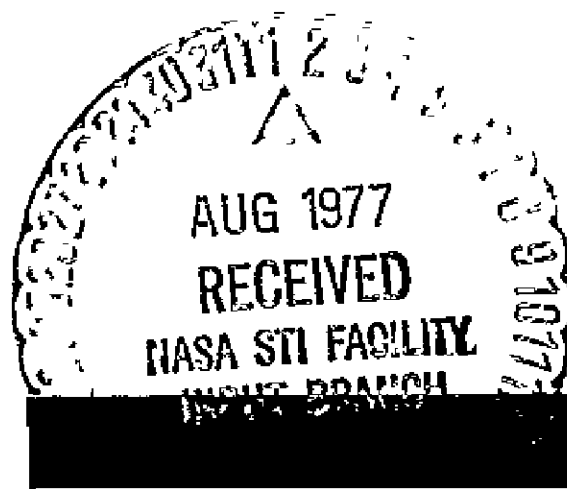


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Application Transfer Activity in Missouri

(January 5, 1976 - January 5, 1977)

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Introduction

The primary objective of this contract has been to facilitate the transfer of remote sensing technology to Missouri users while engaging in remote sensing research relevant to the needs of the state. Mr. Lee Whitebay, UMR and Mr. Terry Barney, UMC have been key research assistants. In addition, numerous graduate students have taken on limited studies which have contributed to the overall objectives of the NASA project.

Initial Planning

An inventory of remote sensor imagery available for use on this project indicated that Landsat imagery and some high-altitude infrared photography was needed. Landsat positive images of the State of Missouri as imaged in early spring, summer and winter were purchased. Also, selected photographs of study sites were obtained. An additive color viewer and Diazo processing instrument were purchased for image enhancement studies.

Study sites selected for land use mapping investigations included all or parts of the following counties: .

Mid-Missouri Planning Region

Boone
Callaway

Mark Twain Planning Region

Monroe
Ralls

Green Hills Planning Region

Calwell
Livingston

Southeast Missouri Planning Region

St. Francois
St. Genevieve

Meramec Planning Region

Phelps
Dent

Study sites selected for the investigation of mined land with remote sensing technology were located in the following counties:

Boone and Callaway	- Coal Strip Mines
St. Francois	- Lead Mine Tailings
Washington	- Barite pits
Gasconade	- Clay pits

In addition, sites in Southwest Illinois and Eastern Kansas were investigated.

Land Resource Classification

Land use mapping from Landsat imagery was begun by undergraduate and graduate students. A number of individual papers and reports documenting interpretation practices were prepared by the students. Field trips to study sites were conducted by the Project Directors as were special seminars in the use of laboratory equipment. This work dealing with Land Resource Classification has led to a final report entitled "Mapping Land Use from Satellite Images -- User's Guide." This report is attached as Appendix A.

In a separate study, a relationship was developed with the Missouri Geological Survey and the Advisory Committee on the Inventory of Surface Land Areas in Missouri Affected by Mining. Research was begun on inexpensive methods of enhancing Landsat imagery for purposes of inventorying mined land. Results to date are presented in the following section.

Interpretation of Mined Land Characteristics from Landsat Imagery

Procedures and Equipment

During the course of this investigation the use of highly sophisticated equipment was kept to a minimum. Only two pieces of equipment (an additive color viewer, and a Zoom Transfer Scope) required the operator to have some expert instruction for good results to be obtained. The rest of the equipment consisted of a Post Micro-Film Viewer, 35mm camera and tripod, acetate, and a "oo" Rapidograph.

When examining a test site the operator began by selecting the appropriate Landsat Images. Four images, one for each band, were loaded into the additive color viewer. The operator then experimented with different filter and light intensity combinations trying to enhance the target area. If the test area could not be located the investigation ended. However, when the results were positive contact negatives were made of the Landsat Images and the study continued. The operator then experimented with various positive-negative image combinations* as well as filter and light intensity combinations.

When the best visual enhancement of the target was achieved, a color slide was made of test area. This slide was placed in a micro film viewer where it was greatly magnified. Placing a sheet of acetate directly on the screen of the micro-viewer, the investigator identified and mapped as many targets as possible.

The delineated map was compared with an overlay drawn at a scale of 1:24,000 using high altitude color infrared photography and a zoom transfer scope. In comparing the two maps, a determination of the relative accuracy of the Landsat interpretation was made.

*Pos-Neg image combinations also referred to as "Masked Images."

The idealized response of a typical masked image is indicated in figure 1.

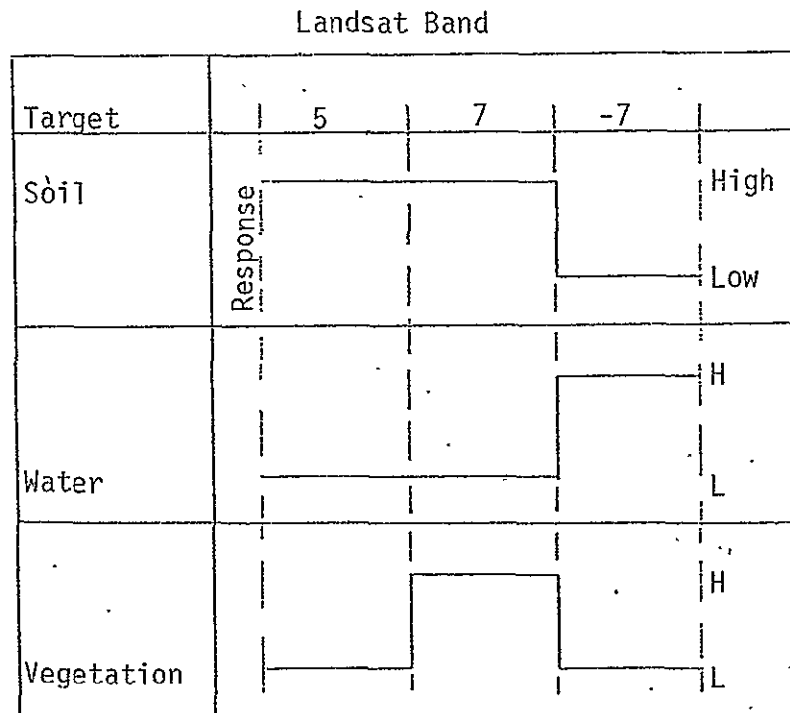


Figure 1

Variations in target colors were achieved as indicated in table 1.

Table 1

Masked Image Response
on Additive Color Viewer*

<u>Landsat Band</u>	<u>Filter Color</u>	<u>Target Color</u>
5	Green	Soil Yellow
7	Red	Water Blue
-7	Blue	Veg. Red
5	Red	Soil Yellow
7	Green	Water Blue
-7	Blue	Veg. Green
5	Green	Soil Cyan
7	Blue	Water Blue
-7	Blue	Veg. Blue
5	Blue	Soil Cyan
7	Green	Water Blue
-7	Blue	Veg. Green

*Assumptions

1. Summer Landsat Image
2. Clear Water
3. Dry Soil
4. Healthy vegetation

Target responses could be generalized as follows:

Dry soil	Light toned, white, light gray, yellow, depending on the filter combination.
Water	dark toned, dark blue to black, if the water is turbid it will appear lighter in tone. Highly turbid tailings ponds could easily be confused for dry soil.
Vegetation	Intermediate tone response controlled by filter selection for band 7.

A procedural guide is being developed for the evaluation of the accuracy and economics of different mined lands interpretation methodologies. Implementation of the study is underway. Preliminary target categories and interpretation characteristics are as follows:

- A. Active Mine Site-Inferred by lack of vegetation, shape, image texture
 1. Stripped Area
 2. Spoil Banks on gob piles
 3. Haul Roads-difficult to detect unless bordered and contrasted with vegetation
 4. Mine structures-none detected
- B. Inactive Mine Sites
 1. Reclaimed Land
 - a. Regraded land-possible tone and texture variation
 - b. Ungraded-tone, texture, water bodies and association with active mine site

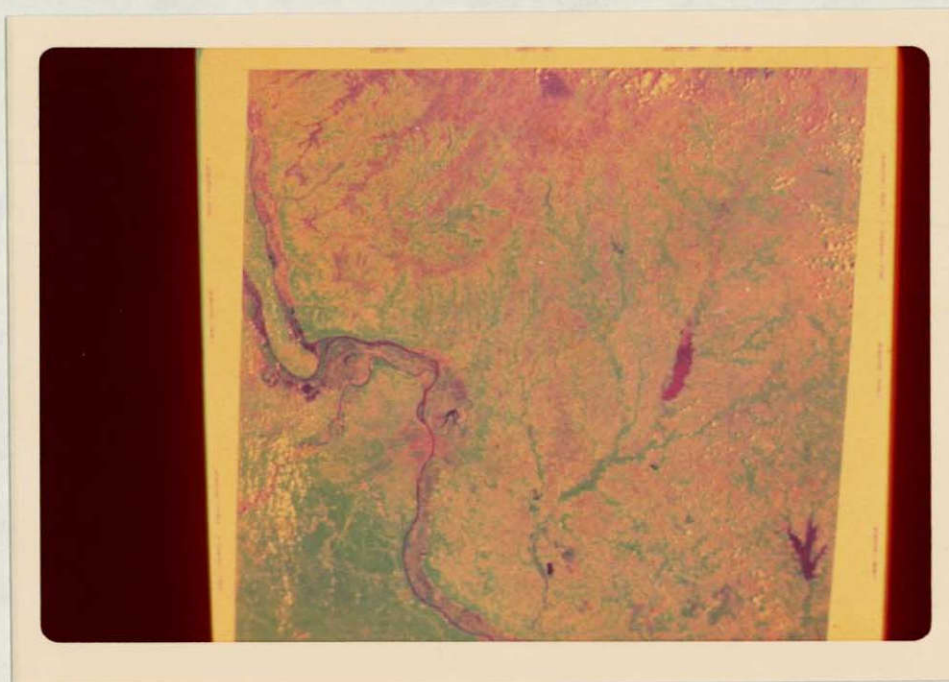
2. Mine Waste Disposal Sites
 - a. Tailings ponds-Turbid water, shape, and regional association
 - b. Spoil or gob piles-lack of vegetation, shape and texture
3. Permanent Water Impoundments-Low reflectivity.

Example Masked Images and Maps

Figure 2 is an example of image masking with color responses typical of those described in table 1. Figures 3, 4, 5 and 6 depict masked images of target sites. The corresponding overlays, although not as detailed as the working maps, serve to illustrate the various target responses.

Figures 7, 8 and 9 are maps delineated from masked Landsat images as displayed on the micro viewer portion of the interpretation system. The photographic step of the general interpretation procedure is outlined in table 2.

Landsat Composite Image I



St. Louis, Missouri - Full 9" x 9" Color Composite from Landsat bands 5, 7 and -7.

Date: 23 May 75

Latitude: 39°

Longitude: 90°

This image was obtained by optically combining bands 5, 7, and negative 7 using an additive color viewer.

Figure 2

Landsat Composite Image II



Southwest Illinois - Coal Strip Mine from Landsat bands 5, 7 and -7.

Date: 23 May 75

Latitude: $38^{\circ} 15'$

Longitude: $89^{\circ} 50'$

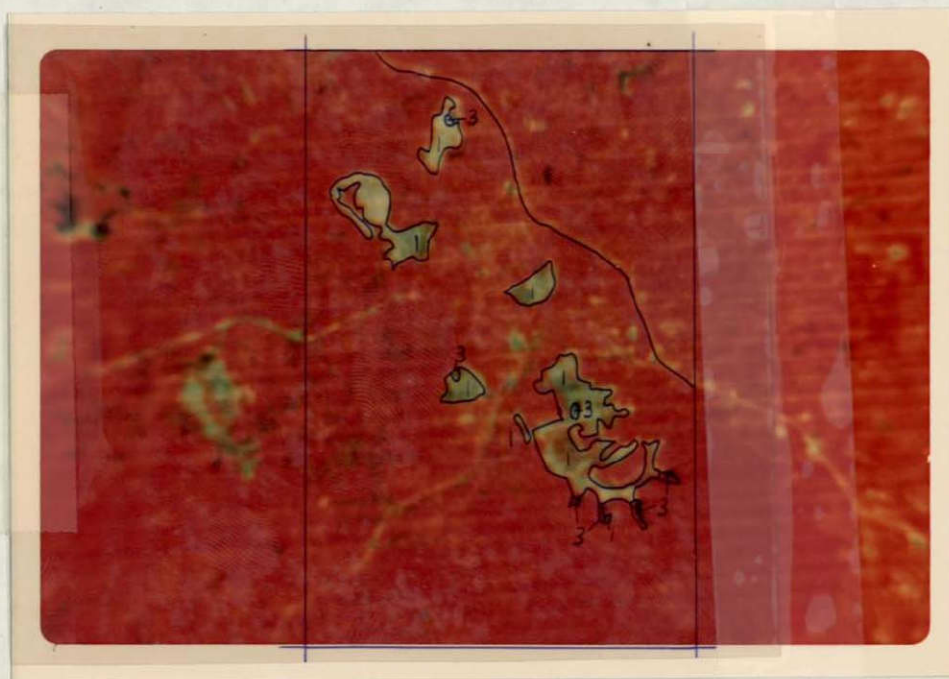
This image was obtained by optically combining bands 5, 7 and negative 7 using an additive color viewer. Careful selection of the color combination and light intensity produces an image which enhances the active mine site, the inactive mine site, and permanent water impoundments.

The light toned tan to pink areas constitute the active mine site.⁽¹⁾ Water⁽³⁾ appears dark purple, and the inactive mine⁽²⁾ site is light green with long thin lakes (purple) running across it.

Figure 3

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Landsat Composite Image III

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Flatriver, Missouri - Tailings and Chat Piles from Landsat bands 5 and 7.

Date: 22 September 1974

Latitude: 37° 50'

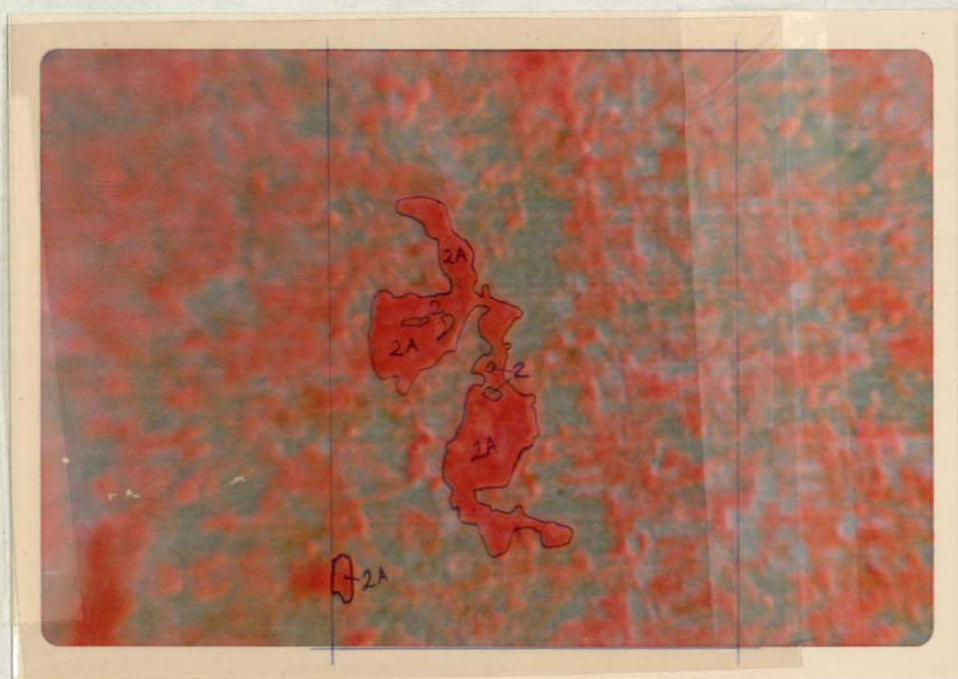
Longitude: 90° 30'

This image was obtained by optically combining bands 5 and 7 using an additive color viewer. Careful selection of the color combination and light intensity produces an image which enhances disturbed areas.

The light toned, blue-gray, areas are tailings⁽¹⁾ and chat piles from deep mining operations. Water⁽³⁾ appears dark blue to black. Vegetation appears red, and highways and urban areas have an orange tint.

Figure 4

Landsat Composite Image IV



Thomas Hill Area - Coal Strip Mine (Abandoned) from Landsat bands 5, 7, and -7.

Date: 19 August 74

Latitude: 39° 40'

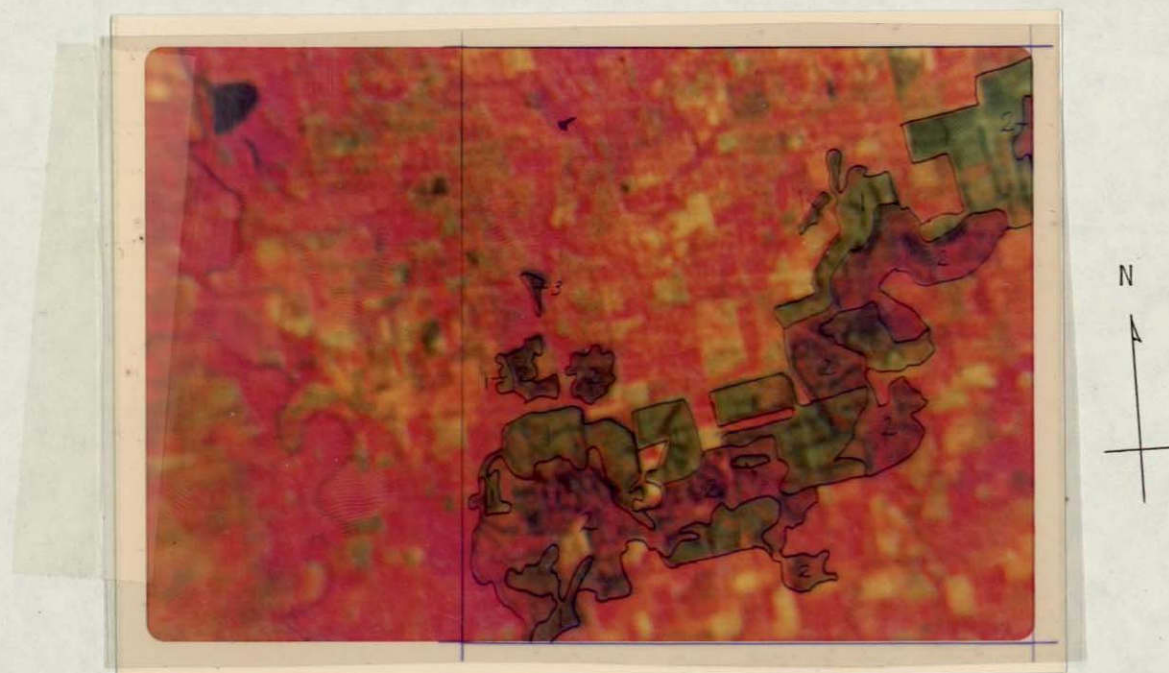
Longitude: 92° 30'

This image was obtained by optically combining bands 5, 7 and negative 7 using an additive color viewer. Careful selection of the color combination and the light intensity produces an image which enhances an inactive mine site. Areas designated 2 are vegetated. The remainder of the site is not vegetated.

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Figure 5

Landsat Composite Image V



Southeast Kansas - Coal Strip Mine from Landsat Bands 5, 7, and -7.

Date: 7 August 73

Latitude: 37° 15'

Longitude: 95°

This image was obtained by optically combining bands 5, 7 and negative 7 using an additive color viewer. Careful selection of the color combination and light intensity produces an image which enhances the active mine site, the inactive mine site, and permanent water impoundments.

The green areas constitute the active mine site⁽¹⁾. Water⁽³⁾ appears dark blue to purple, and the inactive mine site⁽²⁾ is pink to orange with many long thin lakes (purple) running across it.

Figure 6

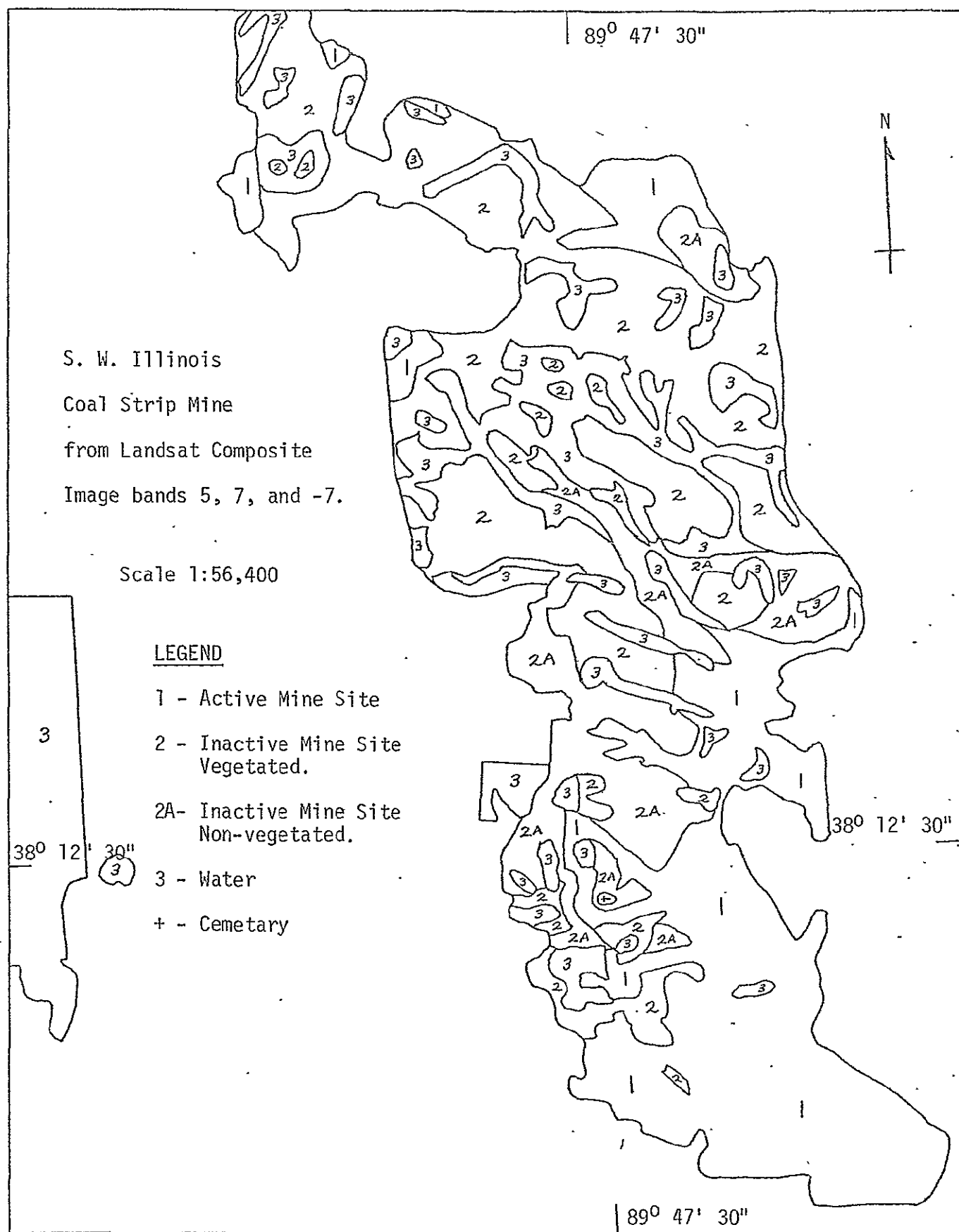


Figure 7

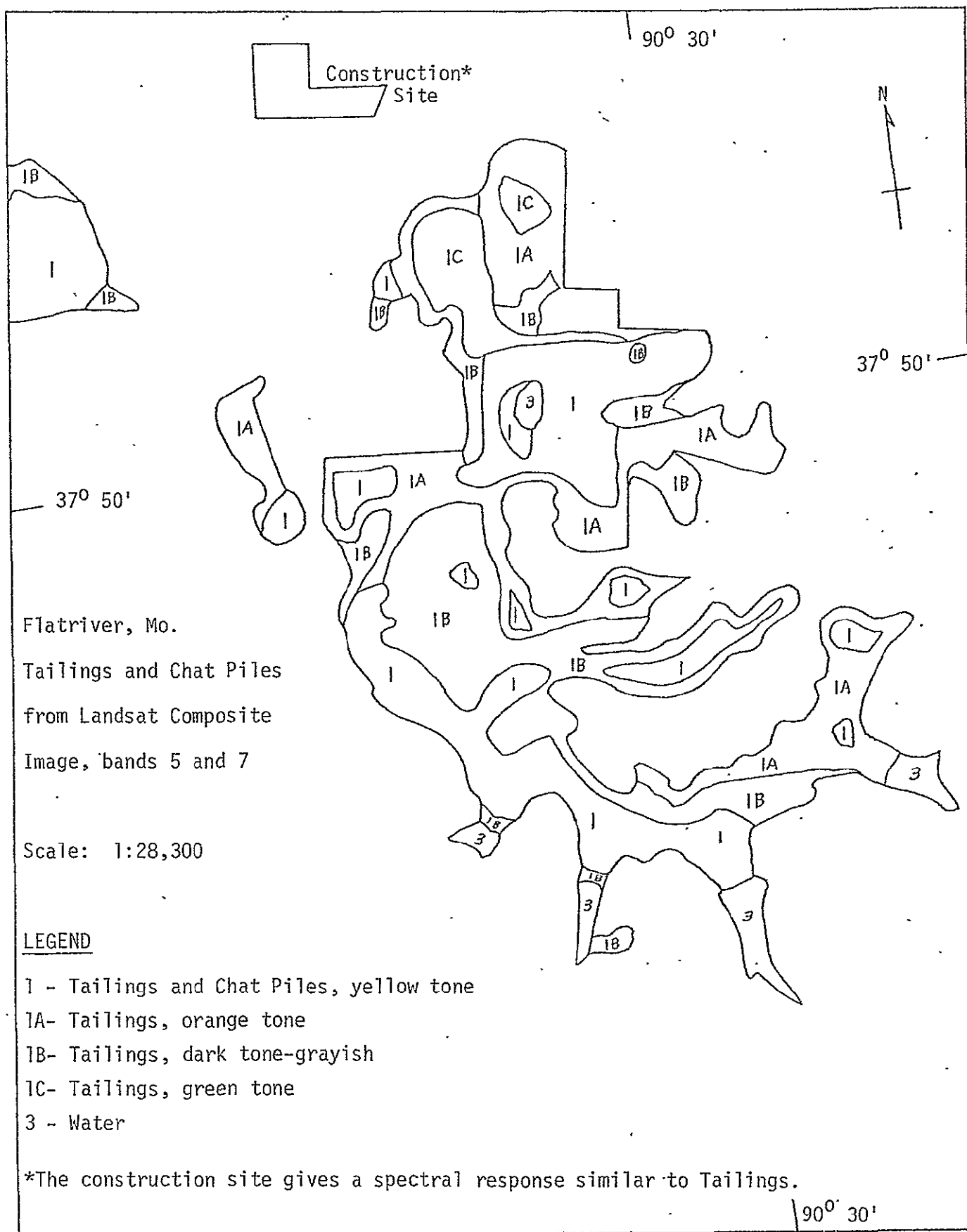


Figure 8

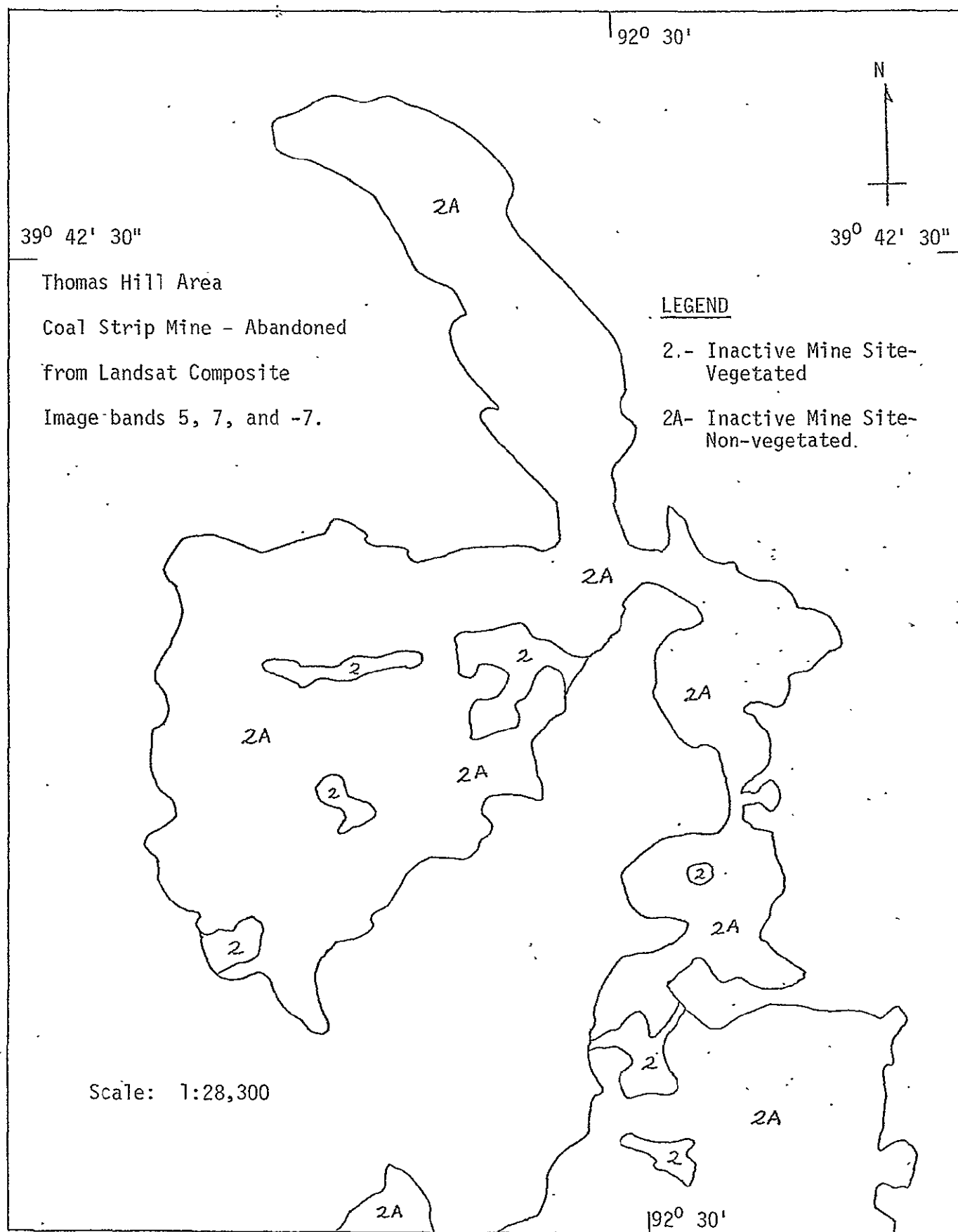


Figure 9

Table 2

Photographic MethodsEquipment

1. 35mm Camera, Honeywell Pentax Spotmatic II.
2. Lense, SMC Takumar 55mm f/1.8.
3. Auto-bellows unit, Honeywell Pentax.
4. Tripod.

Film

1. High Speed Ektachrome (Daylight) EH 135, Kodak.
2. Kodachrome 25 KM 135, Kodak.

Procedure

1. Adjust the Additive Color Viewer to enhance the desired targets.
2. Mount the camera on the tripod, then position the camera so that the entire scene is visible through the view finder.
3. Turn off all the lights in the room.
4. Read the through-the-lense light meter and make the appropriate shutter speed settings.
5. Make sure that the lense system is perpendicular to the Viewer screen.
6. Focus and shoot.

An auto-bellows unit is used for close-ups showing details of the mined areas. It is positioned between the camera body and the lense according to the manufacturers' instructions. Once the unit is in place follow the same procedure as described above.

Measures of Accuracy

One of the major objectives of this study was to determine how accurately mined lands could be delineated from Landsat imagery. Three different measures

of accuracy were considered during the investigation:

1. Accuracy of identifying mined land.
2. Accuracy of actual areal or linear measurements.
3. Geometric accuracy of the image.

The accuracy of identification is quite high. All test sites mines were located except for clay, brown iron ore, and gravel pits. Their small size coupled with a lack of contrast were degrading influences.

Accuracy of actual measurements of the mined lands is very good. Figures 10 and 11 indicate the relationship between minimum target dimension and the percentage of error. For each percentage of error there is a region within which the minimum target dimension will be found. The reason for the range of values is that a target is not only identified by its particular spectral response but also by its contrast with adjacent targets. If two targets contrast with one another such as bare soil versus forest the boundary can be very accurately determined. However if the bare soil grades into a pasture the boundary is less definite hence the error will be larger, or the minimum dimensions must be increased to keep a specific error criteria.

Accuracy decreases as the target size decreases. Measured data indicates that as the minimum resolution capability of the Landsat system (230 ft by 230 ft) is approached the percent error increases rapidly becoming asymptotic to a line drawn at 230 ft. This is due to a number of factors. One factor is the difficulty in successfully interpreting an area only 1 or 2 pixels (pixel = minimum resolution element) in width. Another is that some targets, especially those with very distinct spectral signatures, such as water tend to appear larger than they actually are when their width approaches one pixel. As the target size increases this "ballooning" effect diminishes. Finally, there are mechanical problems associated with physically mapping a small area.

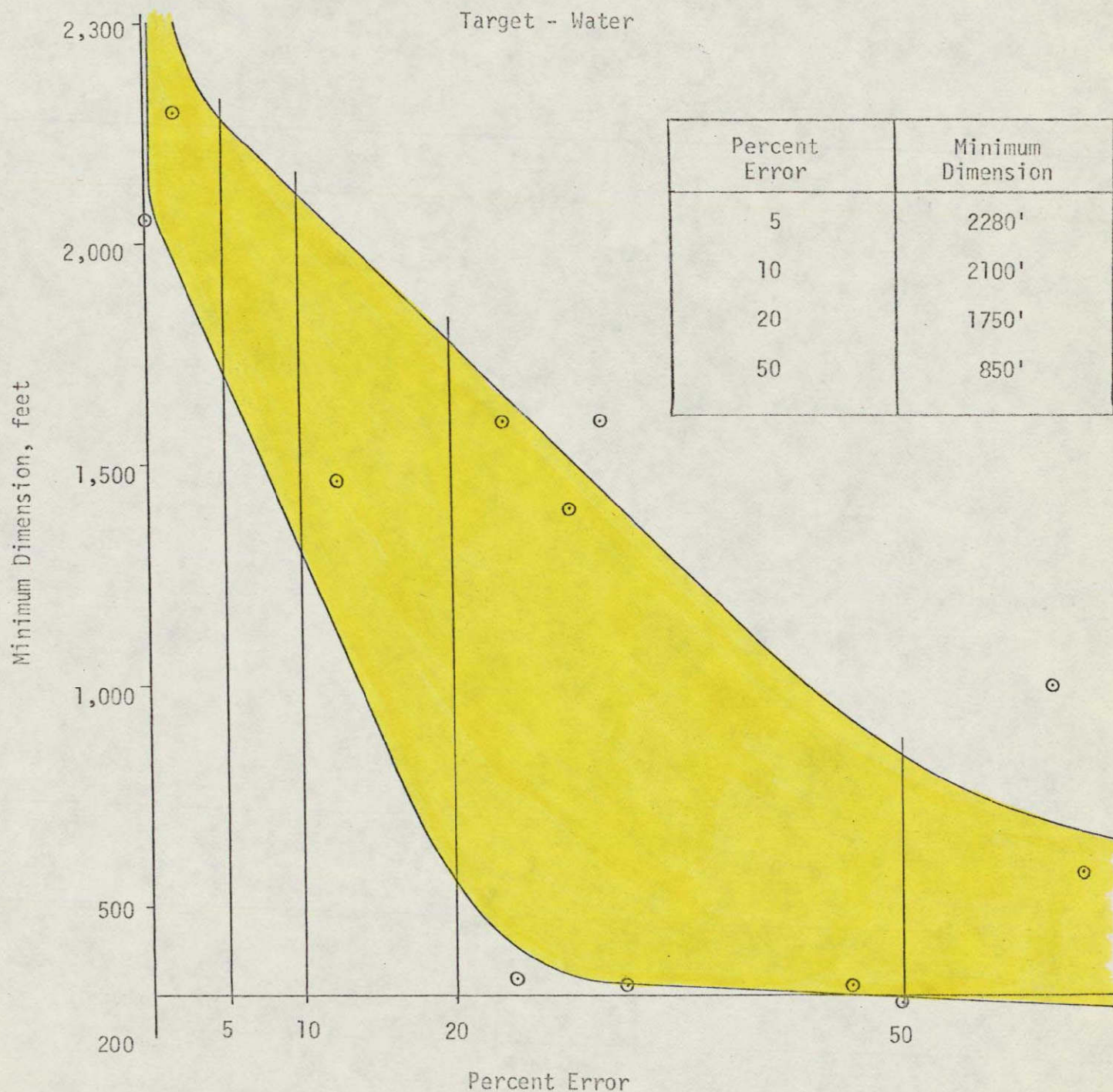
Such factors as placement of the ink line and the thickness of the line are more critical when dealing with a small area where a slight shift in the line will produce a very large error.

The geometric accuracy was not rigorously determined. There is some image distortion in the micro viewer, and while it did not affect the interpretation it must be considered if the information is to be transferred to a standard base map.

One overriding factor which must be considered is the fact that the experience of the interpreter varies. An interpreter must be fully aware of what he or she is looking for and what the Landsat target response will be. An inexperienced interpreter will not produce quality work from this system. However, it requires only a few hours of intensive study, by a motivated individual, to be able to produce acceptable maps.

Percent Error vs. Minimum Target Dimension

Target - Water



$$\text{Percent Error} = \frac{P_D - L_D}{P_D} \times 100$$

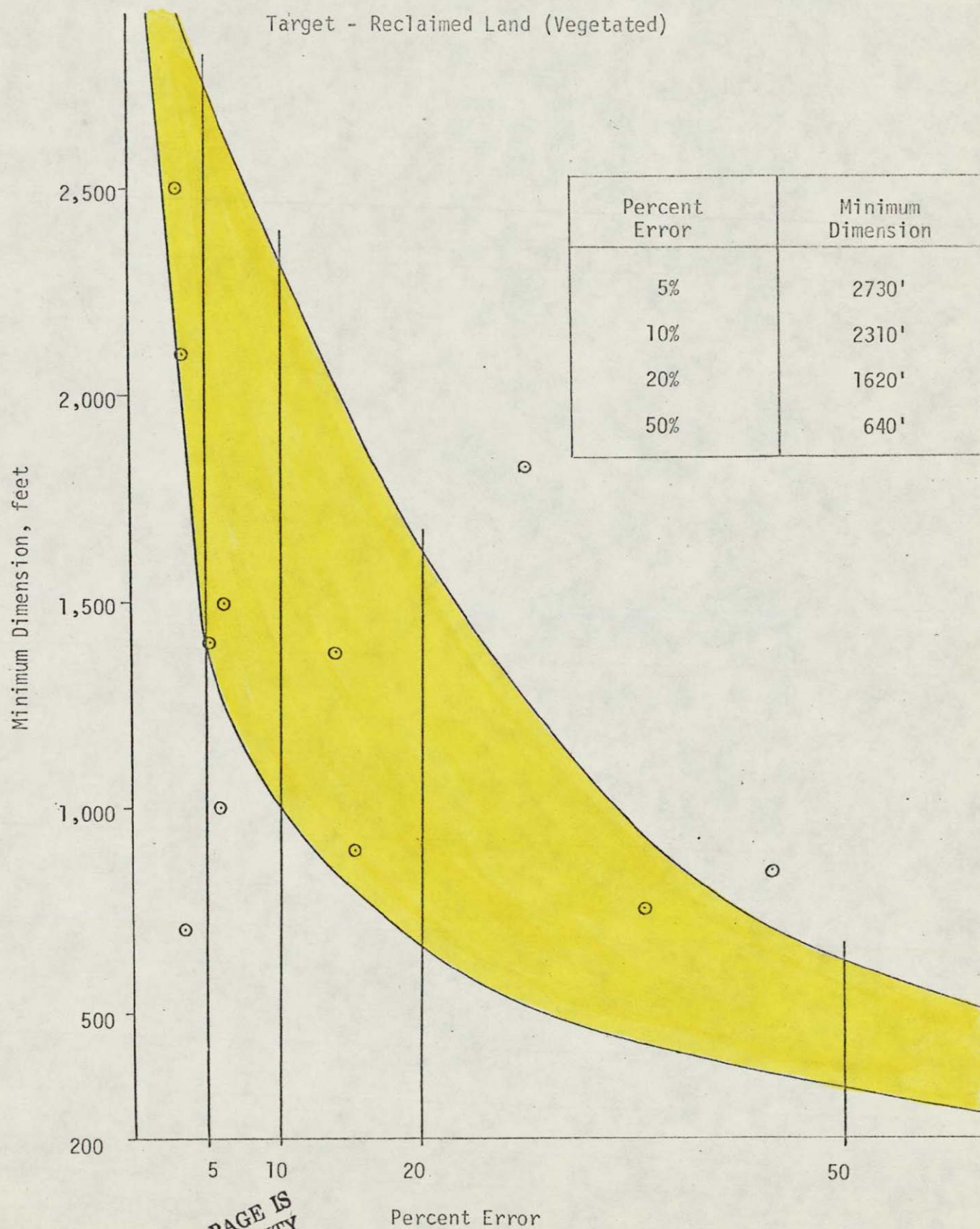
P_D = Dimension of target from photograph.

L_D = Dimension of target from Landsat Image.

Figure 10

Percent Error vs. Minimum Target Dimension

Target - Reclaimed Land (Vegetated)



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$$\text{Percent Error} = \frac{P_D - L_D}{P_D} \times 100$$

Figure 11

Low Cost Interpretation Systems

One of the major results of this research has been the realization of the fact that a digital computer system is not the only accurate way to analyze Landsat data. This study indicates that an accurate system can be developed at a cost low enough to be attractive to organizations with small budgets.

The first system consists of the following:

Equipment	Approx. Cost
1. Additive Color Viewer	\$10,000
2. 35mm Camera and Tripod	\$ 300
3. Micro film Viewer	<u>\$ 400</u>
	\$10,700 Total

The second system is less sophisticated. However it still produces good results. Example images and an interpretation procedure will be developed in the future.

Equipment	Approx. Cost
1. Diazo Printer and Developer	\$ 600—
2. Micro-film Viewer	<u>\$ 400</u>
	\$1,000

Note that all of the equipment has more than one use. Therefore these systems could be attractive to firms which only occasionally handle Landsat images. The systems mentioned above will work for any multispectral system where the data is acquired in the form of black and white photographic transparencies.

Conclusions

Landsat imagery can be enhanced and analyzed with low-cost equipment and procedures. A variety of mined-land characteristics can be interpreted with acceptable accuracy. Procedures utilizing an additive color viewer have been

presented. Work in progress indicates that similar results can be derived from diazo processing and enhancement.

Workshops

Training workshops have been organized and presented as follows:

1. In January and February, 1976, nine presentations involving the use of satellite images for agricultural purposes were given at regional Missouri Soil and Crop Conferences.
2. Two one-day remote sensing workshops were organized and presented. On May 17, 1976 a small group from the Green Hills Regional Planning Commission attended. A group of 18 planners from throughout the State attended on May 18, 1976.
3. Numerous presentations and informal workshop sessions have been conducted throughout the state. A summary of technology transfer activities is given in the contract semi-annual progress report. Other activities have been reported as they occurred.

At the present time, planning is underway for a one-day workshop on remote sensing technology as applied to agriculture and mining. It is hoped that this conference will be co-sponsored by the Missouri Mining Industry Council and held in conjunction with their annual meeting to be held in March, 1977.

Expenditures

Unofficial Expenditures and Commitments*

<u>Salary and Wages</u>	<u>Equipment</u>	<u>Material Supplies</u>
\$7950	\$10,850	\$1983

Indirect costs and fringe benefits of approximately \$5225 have been charged to the account by the Central Administration.

Total expenditures	\$26,008
Contract Budget	\$26,200

*From Departmental Records - Official Accounting handled only by Central Administration, Columbia, Missouri.

MAPPING LAND USE FROM SATELLITE IMAGES

USER'S GUIDE^{1/}

by

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University of Missouri

January, 1977

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MAPPING LAND-USE FROM SATELLITE IMAGES

USER'S GUIDE

Introduction

The launching of the Earth Resources Technology Satellite (formerly called ERTS) now called LANDSAT has initiated a new era in the application of remote sensing technology to land resource inventory. Results of numerous experimental applications of LANDSAT data and images indicate a strong potential for this technology as a primary data source for generalized land use and land cover mapping.

This guide outlines a visual interpretation approach for interpreting and mapping general land cover types (called Level I) from LANDSAT color composite images at a 1:250,000 scale. The guide is designed for Missouri user's who (1) have little or no experience with satellite imagery, (2) want to minimize their expenditures of time and financial resources, and (3) have limited or essentially no access to equipment normally used in image interpretation.

This guide describes a direct tracing methodology which consists of five basic steps:

1. The user gathers background information about the area to be mapped and becomes familiar with the geographic extent of that area.
2. The user becomes acquainted with the LANDSAT image.
3. The user selects a classification system or scheme to assist in an organized approach to interpreting the image.
4. Overlays of the study area are prepared from USGS 1:250,000 scale maps and registered on the LANDSAT image.
5. Land cover categories are interpreted according to the classification system used and boundaries are mapped on the overlay utilizing the LANDSAT image as the mapping base.

Each step is described in detail for the benefit of the most inexperienced user. The procedure is simple and straight forward and can be modified depending upon the skills and resources of the user. The description of the mapping procedure is followed by a short discussion on image interpretation. A description of the LANDSAT system and information on ordering imagery have been included as appendices following the text.

Step 1 - Area Familiarization

The user should begin by determining the location of the area to be mapped on an appropriately scaled base map. This is helpful in becoming familiar with the extent of the geographical area to be mapped and also in locating the defined study area on a LANDSAT image. One will also find that familiarity with the coordinate locations of longitude and latitude for the area are helpful in ordering the correct LANDSAT image.

The base map should be large enough in scale to provide an adequate overview of the study area. USGS 1:250,000 scale maps are recommended since the detail of these maps include major highways, towns, civil boundaries, primary drainage and contours as well as a grid of the longitude and latitude. Another advantage of the USGS maps is that they can be used in developing the overlays upon which the land cover category boundaries can be mapped. For study areas that consist of 10 or more counties, one should consider using the 1:500,000 scale Missouri state base map. USGS 7½ minute and 15 minute quadrangle sheets and Missouri State Highway Department county road maps are helpful for providing additional details. All of these maps are standard products and readily obtained. (See Appendix I)

As part of the detailed orientation to the study area, the user should collect as much background information as possible. The more a user knows about the area to be mapped, the better that user will be able to interpret from the image. Background information is especially helpful in strengthening the user's interpretation abilities in those areas where one lacks familiarity or experience. Helpful sources of background information are:

1. Topographic, geologic and hydrologic maps. These maps will provide an insight to the drainage patterns of an area as well as the lay of the land. Areas of steep slopes which readily affect cover type and land use are more readily delineated. Sometimes sharp demarkations between geologic parent materials can be seen on satellite images.
2. County road maps. Road maps are helpful for scale adjustment purposes and for orientation to specific locations. Roads have a tendency to be distinguished on the image because the reflectance of the road is much higher than that of the cover types around it. The verification of drainage features such as lakes and rivers as to their specific location are helpful through the use of county road maps. The road maps will also be helpful for later ground verification and determining the route of travel.
3. Previously compiled land use maps. Usually maps have been compiled by rural development groups or for community development studies. These maps give a better indication of what cover types to look for. Land use changes are quite noticeable, especially when image responses appear different than shown on the land use maps. An example would be a recently cleared timber area that is now in pasture.
4. Aerial photographic coverage. Mosaics of low altitude photography such as ASCS photographs (1:24,000) or copies of high altitude photography (1:120,000) help to verify cover types. One can readily determine the locations of timbered areas and assess the density of these areas from the photography. This is extremely helpful when interpreting the intensity or color tones seen on the satellite images. In addition to helping one to become familiar with the area, photography can also serve as a useful ground truth instrument.

5. Crop calendar: The user should be familiar with the expected stages of maturity of different crops at the time the image was taken. A crop calendar would show the stages of maturity of the different crops and an estimate of the percent of fields that have reached a specific maturity date by a certain date. Crop maturity may be the only way that one can separate small grains from row crops. It is also helpful to know information about specific cultural practices as applied to a crop. For example ground that has been prepared for planting for row crop would appear different on the image than an area that still has crop residues at the soil surface.
6. Weather data. Many unusual patterns on LANDSAT images can be explained by weather; primarily precipitation variations. One should check the rainfall and temperature information for all weather stations in the area for at least a month prior to the time that the image was taken. For example, one might check a crop calendar and determine that farmers are unlikely to fall plow before an August frame of data was taken. However if adequate rain is received during July and August, the farmers are likely to begin plowing early and these areas might be mistaken for wetland areas. This would be especially true if a rain had been received 24 to 48 hours prior to the time that the image was obtained.
7. Soil surveys. The general soil map prepared for a county soil survey is the most helpful for familiarizing the user with basic soil differences in an area or county. The soils will have an effect on the type of crop grown, cultural practices performed and date that these practices are initiated. It was noticed in one of the study sites that the timber appeared different in the central region of the county. Checking with a soil survey map it was found that this area of poor timber response had an abundance of fragipan soils. The poor timber growth on the fragipan soils became very evident on the satellite images. Many times one needs to compare the soil differences and the weather information to explain differences on the images.
8. Natural resource inventories. Information about specific resources in the area are helpful. Crop acreages will tell the user the percent of the area to expect in row crop versus small grain. Total number of livestock can be equated with pasture acreages. Population figures will give an indication of urban density to expect in an area. The population growth figures are also helpful for interpreting new residential areas.
9. Regional monogram or profiles. All of Missouri's regions have regional profiles which were prepared by the Regional and Community Affairs. These publications show specific information on transportation, institutions, occupations, agriculture, economics, and many other factors. This information is extremely helpful for understanding an area and for interpreting responses seen on a satellite image.

Step 2 - Image Orientation

The user needs to be familiar with the LANDSAT image before any attempt is made at serious interpretation or mapping. This section explains some specific items important to understanding a LANDSAT image. The mapping methodology in this procedure uses 1:250,000 scale color composite (simulating color infrared) paper prints. This format was selected for the following reasons:

1. It does not require the user to perform additional photographic enlargements.
2. No special equipment is needed for interpretation purposes.
3. This is the largest scaled standard LANDSAT product available and therefore easy to obtain.
4. It is readily understood by persons not familiar with satellite imagery.

The Plotting and Mapping Base. The LANDSAT image functions as the plotting base and as a map base for the mapping procedure. The plotting base is a map or photo mosaic used as a positional guide for the compilation of map data (Widel, 1974). The map base is generally a map or image upon which the land cover boundaries are delineated. Although the LANDSAT images are not completely free of distortion, their use as a base provides an acceptable degree of positional accuracy relative to a scale of 1:250,000.

Image Scale. The image scale of 1:250,000 (this means that one inch on the photo image equals 250,000 inches on the ground) is large enough for accurate interpretation of many different land cover types. The opportunity to purchase imagery at this mapping scale eliminates the need for consideration of enlargement equipment and accompanying problems. This scale image is also compatible with the USGS 1:250,000 scale topographic sheets for which there is complete coverage over Missouri.

The 1:250,000 scale is the best compromise in terms of cost, time, product availability and mapping accuracy for specific land cover categories. As the user gains more experience or has a very specific task, a larger scale should be considered. Black and white images at a larger scale have been useful for delineating forest cover from other land cover types within the state. Black and white satellite images have also been used to map mined lands at 1:24,000 in Missouri. The time of year needs to be carefully considered when ordering images regardless of the scale that is used.

Product Size. The 1:250,000 scale LANDSAT paper reproductions are 36 inches by 36 inches in size. These products are quite durable. However, they are an awkward size, difficult to handle, and will crack or bend if not left flat or properly rolled. All work should be done at an uncluttered table with a smooth surface and enough area provided to support the entire image.

The LANDSAT paper products are slightly transparent and therefore can be used on a light table to obtain additional enhancement of color tones. This is an optional feature of the product and is not a necessity for accurate interpretation. A person can trim the satellite image to the county or size of the area of interest for better handling. This would be especially helpful if one has a small light table. A special frame was built around a small light table to accommodate the 36 inch by 36 inch paper photography and prevent bending or cracking during use in one project. If a light table is not used, one must provide the correct lighting source and angle for best distinction of color tones and elimination of glare. This is accomplished by trial and error.

The LANDSAT Scene. The color composite product provided through the EROS Center is bordered in white and framed by a black background. This LANDSAT scene is the actual area imaged by the satellite sensors. (See Figure 1) As the satellite was scanning the scene from north to south, the earth rotated 13 kilometers (8 miles) from west to east. This places the lower left corner of every LANDSAT scene 13 kilometers farther west than the upper left corner. Also due to the design of the orbit, the scenes are not oriented to true north. The scene is oriented approximately 18° east of true north. (See Figure 2) Each scene covers approximately 34,000 square kilometers or approximately 13,000 square miles. A square inch would therefore equal 10,240 acres at a scale of 1:250,000. (See Figure 3)

Image Colors. Each LANDSAT scene is imaged in four spectral wavelength bands. A black and white photographic image can be produced for each individual wavelength band. (See Table II-2 in Appendix II) A color composite is a combination of three of the four bands and offers the user a balanced blend of the unique contrast brought out in the individual bands. This eliminates the need to purchase four separate images. (See Appendix II) Color is the most interpretable feature on a photograph. This is especially true for satellite images which cover large areas at small scales with relatively low resolution. A LANDSAT color composite is usually easier to interpret than a single gray scale image because the human eye is more sensitive to a greater range of colors than it is shades of gray.

The user should not be concerned about the meaning of each color tone or pattern visible on the image during the orientation step. In general, the pink and red tones are living vegetation. Images taken when deciduous trees are fully leafed out will display forested areas as the darkest red. Images taken prior to the time that the trees have leafed out will display forested areas as a greenish brown color. Water tends to be black to light blue with deeper water bodies being the darkest in color. Water bodies containing large amounts of sediment or of shallow depth will be light blue. Urban areas tend to be a medium to blue gray. Highways appear as narrow white lines. Bare soil will range from black to green to white depending upon moisture content and organic matter of the surface layers.

To become more familiar with the association of a specific color to cover types, the user should locate several land cover types on photo index sheets or on black and white conventional photographs. It is a useful exercise to place a clear acetate overlay on the mosaic and

Figure 1

Landsat Image

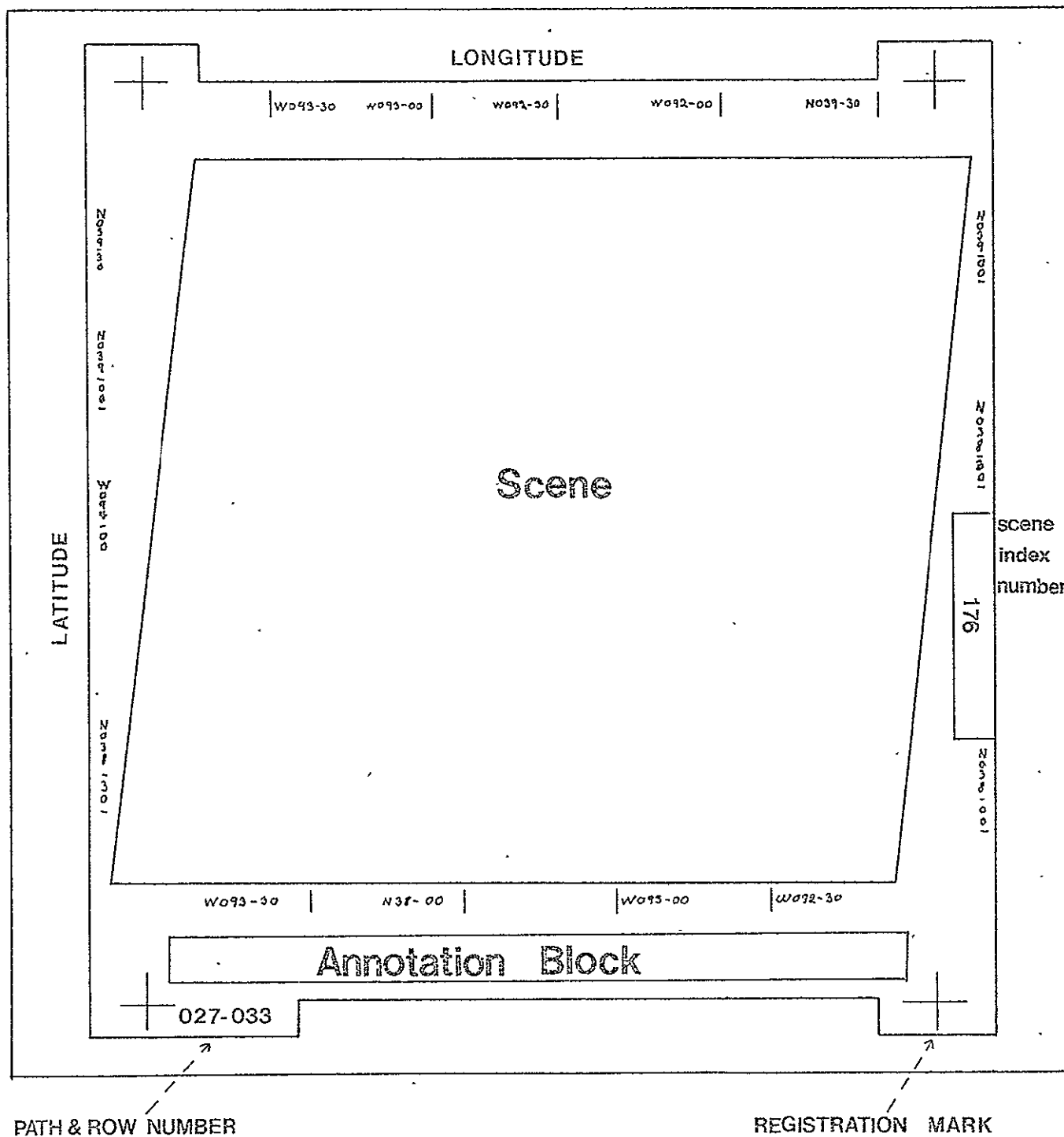


Figure 2

Landsat Scene Orientation

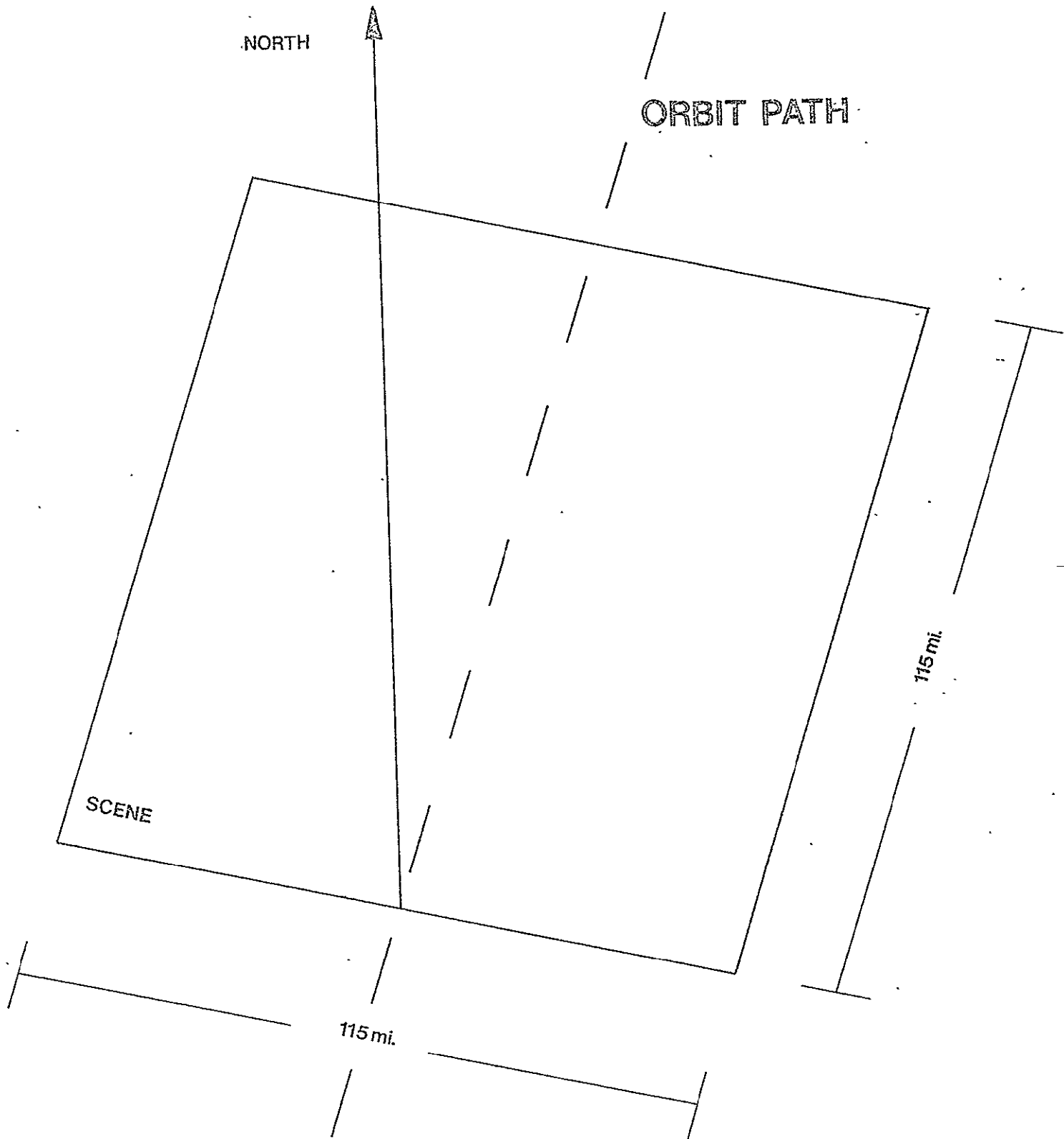
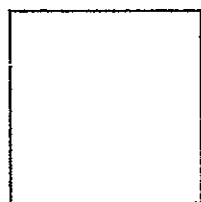


Figure 3

ACREAGE TEMPLATE



10,240 Acres



2,560



640



160



40



10



2.5

SCALE 1 : 250,000

map out some of the general land cover categories such as forest, urban, agriculture and water. The user should then attempt to recognize the same land cover categories at the same locations on the satellite image. Remember that there will be a difference in scale for which the user needs to compensate when comparing areas on the photograph with those on the satellite image.

Annotation Block. An annotation block contains specific information about the location and identification of the LANDSAT frame. The annotation block is printed on the white border under each LANDSAT scene. The first and most important notation of the block is the date the image was taken. The date is the user's most important clue to understanding the various color tones and patterns found on the image. One needs to consider the climatic and growing variables during a season as they can vary dramatically from year to year. This would result in different color tones for scenes taken at approximately the same time of year. A complete explanation of the annotation block is found in Figure 4.

Latitude and Longitude Grid. Along the white border of each LANDSAT frame are regular markings sometimes called tick marks which indicate the degrees of longitude and latitude. A grid can be constructed by connecting the tick marks that follow each numbered designation. The images are slightly skewed and therefore the designation of latitude will sometimes appear on the north and south sides of the image while the longitude designations may appear along the west and east sides.

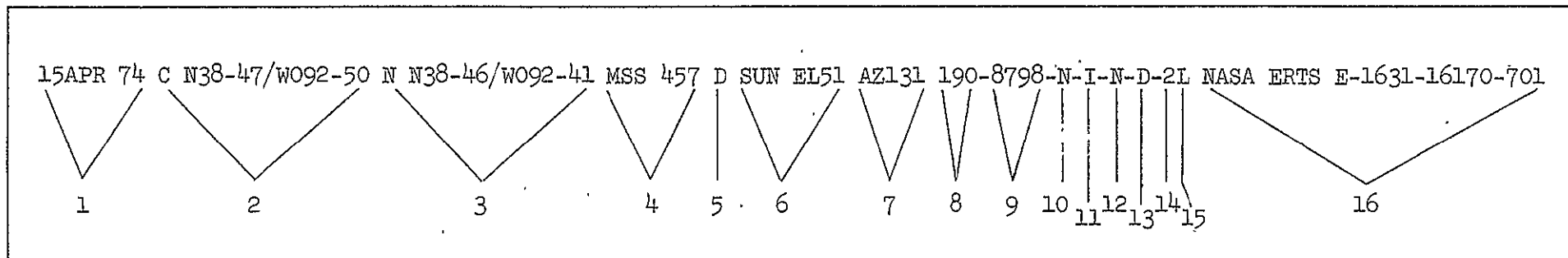
Registration Marks. Along every corner of a LANDSAT image will be a cross mark or plus sign. These are called registration marks and are useful for several purposes. If the user attempts to make color infrared composites, the registration marks will be extremely helpful for registering the responses from the different wavelength bands. Some users might find it helpful for overlaying information from one wavelength band and comparing it to the information of another wavelength band. The registration marks can also be used when developing a map as an overlay over the image. Marking the registration marks on the overlay will assist in orienting the overlay each time that it is placed over the LANDSAT image.

Orientation. The large regional coverage by each satellite image and the high altitude (570 miles) from which the landscape is imaged combine to give the LANDSAT imagery a dynamic quality which is often lacking in larger scaled aircraft photography and conventional maps. The user should take as much time as needed to adjust to this unique perspective of the earth's surface.

Upon first seeing the image, the user should scan the entire frame looking for familiar cultural and physical land marks. This will help put the entire geographical area of the scene into proper perspective. Using the base map selected in Step 2, or a state highway map, locate the larger towns, rivers, lakes, reservoirs, and highways on the image.

If the area of interest to the user is not found on one USGS 1:250,000 scale map sheet, then the user should mosaic the map sheets together to cover the entire scene. This mosaic can be overlaid with a sheet of clear acetate. All county boundaries can be delineated by using a black

LANDSAT IMAGE ANNOTATION BLOCK



- 1) Day, month and year image acquired
- 2) Coordinates of image center point in latitude and longitude
- 3) Position of satellite when scanning the center of the image scene
- 4) Wavelength bands used in making color composite
- 5) D - Data transmitted directly
R - Data tape recorded
- 6) Sun elevation - Measured clockwise from true north
- 7) Sun azimuth - Measured clockwise from true north
- 8) Spacecraft heading to nearest degree measured clockwise from true north
- 9) Revolution of satellite since launch
- 10) Letter code for station receiving data
- 11) "I" image is full sized
- 12) N - Image processed normally
A - Abnormal processing
- 13) Method used to compute image center
P - Predicted orbit ephemeris data
D - Best fit ephemeris data
- 14) Signal mode used to transmit data
1 - Linear mode
2 - Compressed mode
- 15) Gain settings for Bands 4 and 5 if used in the image
H - High
L - Low
- 16) Frame (image) identification number

Figure 4

felt tip pen to mark the boundaries. One should be careful to register the overlay by marking the registration marks previously discussed. With the completion of the acetate overlay, the user's attention can now be focused on a particular county or group of counties and specific land marks can be more readily recognized.

Step 3 - A Classification System

A classification system provides a means for the user to group the different land uses or cover types that one wants to recognize. This system in essence becomes the legend or key to the map produced. The system may be designed by the user or the user can select an existing classification system which might be modified to meet specific needs. The USGS has proposed a Level I and II land use and land cover classification system for use with remotely sensed data (Anderson, 1976). The Level I categories established for this system can be accurately interpreted from LANDSAT images.

This system (See Table 1) is designed as a standardized approach for nationwide land use data collection efforts. The categories are defined so that a minimum level of interpretation accuracy is required. The user should be aware that categories and accuracy levels of this system can be altered to meet the needs and interpretation capabilities which the user possesses.

Step 4 - Preparation of Overlays

Acetate overlays can easily be prepared utilizing the USGS 1:250,000 scale topographic sheets as base maps. Study areas requiring two or more map sheets should be combined to form a mosaic. The maps are designed so that the sheets can be joined along lines of longitude and latitude. The sheets can easily be joined with rubber cement. If the sheets are to be separated and reused, masking tape can be used as a fastener. Care should be taken to avoid damaging the maps when the tape is removed.

The user has a variety of materials from which to choose when selecting overlays. Drafting film that has been frosted on one side is often used. This material will accept both pencil and ink making it easy to work with. However, the frosted treatment tends to obscure the image to a degree that it makes it difficult to interpret accurately. Specially treated clear acetates are available that take drafting ink and overcome the problem of obscuring the color tones and patterns on the image. The user might consider using pencil or inks that can easily be removed when first initiating the mapping process in order to make corrections. Clear acetate is vulnerable to scratching and smudging and the user should be careful in handling and storing this material.

Placing the overlay material over the base map, secure each corner with masking tape. Using a number one rapidograph pen and straight edge, ink in the study area boundaries. Major highways appearing on the image should also be inked. This helps in registering the overlay to the image more readily. One should avoid marking in all roadways and similar features since they may make it more difficult to recognize the different land cover categories as they are delineated. If the user desires to have a lot of detail on the acetate, consideration should be given to developing individual overlays showing hydrology,

TABLE 1
LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE
WITH REMOTE SENSOR DATA*

LEVEL I	LEVEL II
1 Urban or Built-up Land	11 Residential. 12 Commercial and Services. 13 Industrial. 14 Transportation; Communications, and Utilities. 15 Industrial and Commercial Complexes. 16 Mixed Urban or Built-up Land. 17 Other Urban or Built-up Land.
2 Agricultural Land	21 Cropland and Pasture. 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horti- cultural Areas. 23 Confined Feeding Operations. 24 Other Agricultural Land.
3 Rangeland	31 Herbaceous Rangeland. 32 Shrub and Brush Rangeland. 33 Mixed Rangeland.
4 Forest Land	41 Deciduous Forest Land. 42 Evergreen Forest Land. 43 Mixed Forest Land.
5 Water	51 Streams and Canals. 52 Lakes. 53 Reservoirs. 54 Bays and Estuaries.
6 Wetland	61 Forested Wetland. 62 Nonforested Wetland.
7 Barren Land	71 Dry Salt Flats. 72 Beaches. 73 Sandy Areas other than Beaches. 74 Bare Exposed Rock. 75 Strip Mines, Quarries, and Gravel Pits. 76 Transitional Areas. 77 Mixed Barren Land.
8 Tundra	81 Shrub and Brush Tundra. 82 Herbaceous Tundra. 83 Bare Ground Tundra. 84 Wet Tundra. 85 Mixed Tundra.
9 Perennial Snow or Ice	91 Perennial Snowfields. 92 Glaciers

* Anderson, U.S. Geological Survey Professional Paper No. 964, 1976.

state and federal road networks, cultural features, and topography as drafted from the USGS base maps. (See Figure 5) Copies of overlay plates for the individual USGS 1:250,000 series can also be purchased. These overlays can then be placed between the color composite image and the primary overlay to assist the interpretation process.

The user will find that the overlays will seldom, if ever, register perfectly to the LANDSAT image. Although the loss in positional accuracy is not a serious problem for Level I interpretation, the user should be aware of the factors causing the discrepancy. The LANDSAT image, in standard product form, is not geometrically rectified. The high altitude of the satellite eliminates most of the relief distortion but there are geometric errors in the image due to the earth's rotation and navigational variances of the space craft. There may also be inaccuracies in the USGS maps due to data compilation and printing. Positional error is also introduced when the USGS sheets are mosaiced. It is difficult to join the sheets perfectly due to the curvature of the earth.

To assist in registering the overlay to the image, it is best to use natural boundaries like rivers and cultural features like highways and man-made lakes and reservoirs. To insure accurate registration of the overlay on the image and for the placement of additional overlays, registration marks should be placed on each overlay. At least two corners of the overlay should be marked with the registration marks. There are standard tape products of registration marks that one can order for this purpose.

Step 5 - Mapping

The mapping step is divided into two stages: development of a generalized map (Stage 1) and developing detailed maps (Stage 2) which depend upon such factors as the clarity of the image, season of the year the image was obtained, the interpreter's ability and other factors.

Stage 1 - Generalized Mapping. A very generalized map can be compiled that outlines each major land use category. The user should simply draw lines around areas that appear similar utilizing the knowledge gained from reviewing previous maps and data of the area being mapped. Categories can be combined if the user has difficulty in making immediate distinctions between certain categories.

Combining categories was used in compiling the maps shown in Figure 6 - 8. The interpreters could not make a distinction between pasture and row crops with any degree of confidence on their first interpretation attempts. They therefore combined the two categories and continued the mapping process over the entire area. It is important that the user gain confidence in combining the gross categories and have a feel for the type of cover types or land uses that have been combined or are included within the category.

There are several ways to check the accuracy of the generalized map. One can compare it with a recently acquired aerial photography of a portion of the study area. High altitude photography at a scale of 1:120,000 is excellent for this purpose since one would have a minimum of scale confusion. The interpreter can also determine the location of specific categories in relation to a county road map and check the categories by driving the roadway in an automobile. It is useful to

Boone Co.

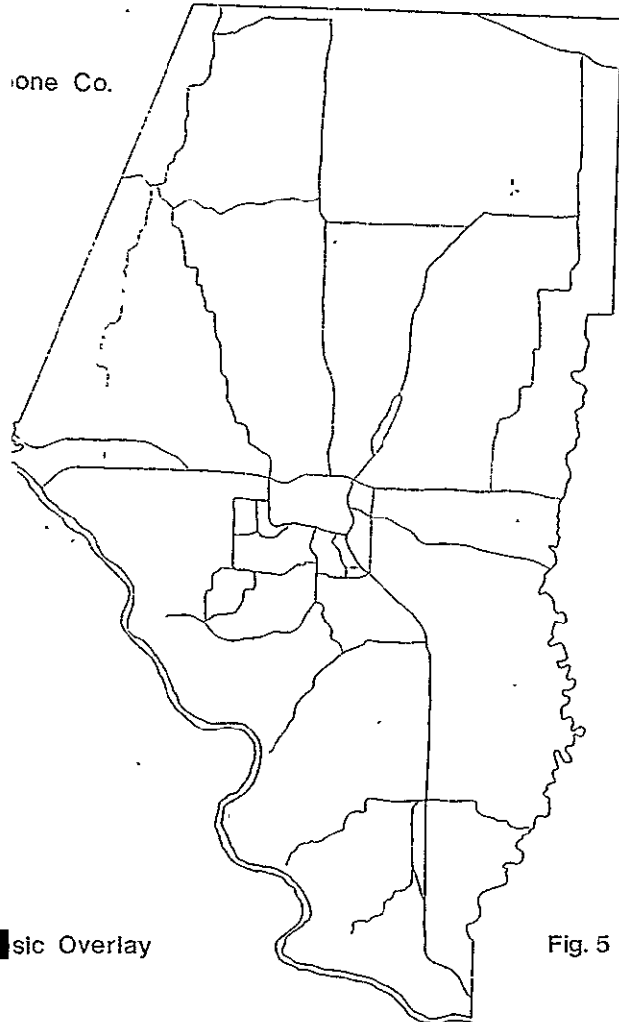


Fig. 5

Boone Co.

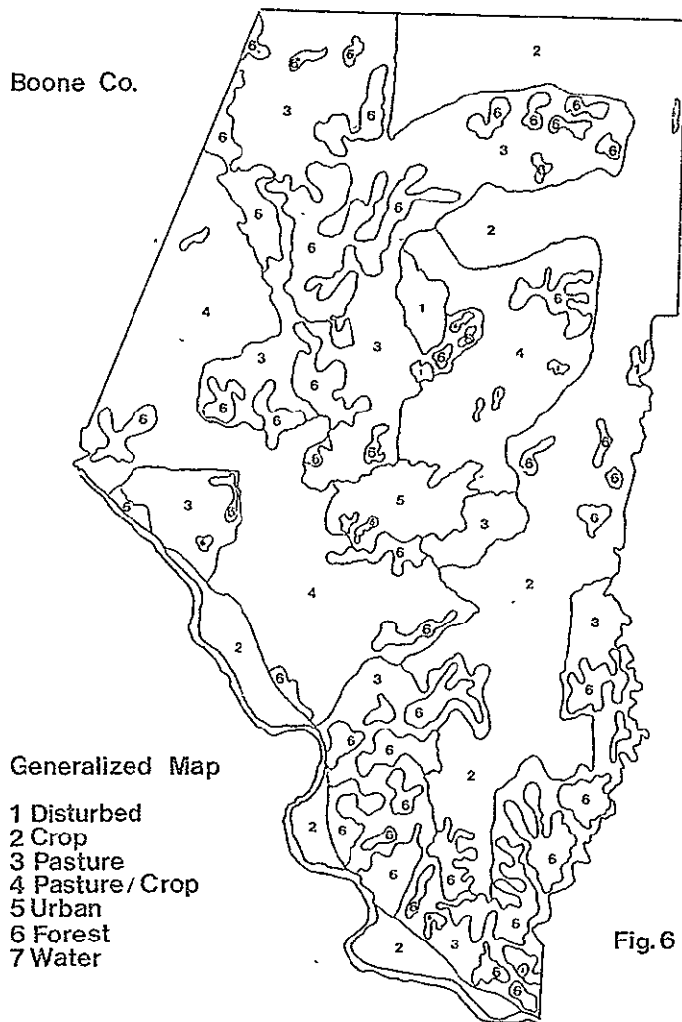
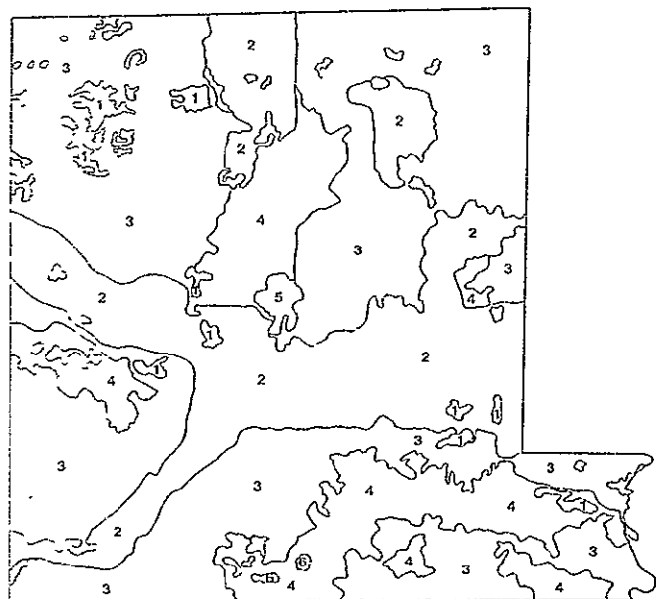


Fig. 6

Livingston County

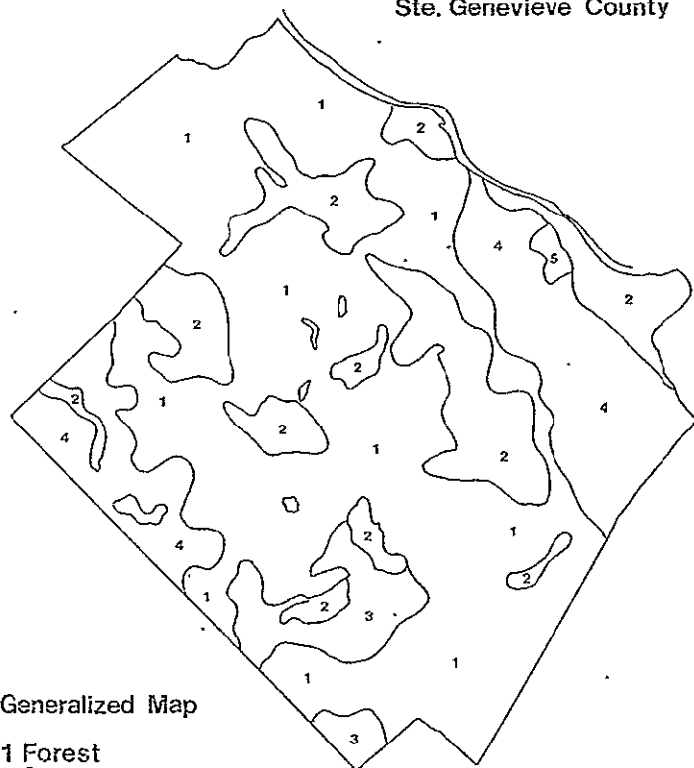


Generalized Map

- 1 Forest
- 2 Crop
- 3 Pasture
- 4 Pasture/Crop
- 5 Urban
- 6 Disturbed

Fig. 7

Ste. Genevieve County



Generalized Map

- 1 Forest
- 2 Crop
- 3 Pasture
- 4 Pasture/Crop
- 5 Urban

Fig. 8

transfer the generalized map onto a county road map when actually checking in the field. One can use USGS 1:250,000 scale maps as a guide in making the transfer. When making a field check, take the satellite image with you to make visual comparisons between what is seen on the image and actually found on the landscape. This will help in establishing the association between color tones and patterns seen on the image and their corresponding land cover category. Field inspections are most effective if they are made at a time comparable to the date (season and month) that the image was acquired.

Stage 2 - Detailed Mapping. In this stage the user should attempt to remap the study area utilizing the information gained from inspection of aerial photography and/or field inspection. It is important at this time to determine the categories of a classification system to be used. The user should delineate the smallest areas that the eye can see and that the pen can be drawn around and still distinguish the category. Figures 9 - 15 were compiled in this manner. A fairly large area should be mapped before consulting the ground truth techniques used in Stage 1.

It is important that a sampling procedure be implemented, if possible, to estimate the accuracy and increase the interpreter's confidence in the maps produced. The sampling procedure should be random, stratified and employ a confidence interval to minimize statistical bias. Sample size is also important. As a general rule, a larger sample is needed as the number of areas outlined and classified on the map increases. Also, if one establishes confidence intervals, they are dependent upon sample size. An actual field check can be made of the sample points or checked against appropriate, larger scaled aerial photography.

Assessing the accuracy of the final product is a complex and challenging task. The user must keep in mind the many errors that can be introduced in the interpretation and mapping tasks as well as the statistical biases of the sampling procedure when attempting to evaluate the results either qualitatively or quantitatively. Accuracy estimation are affected by many different variables: interpretation and cartographic skills, classification system used, complexity of area being mapped, image quality, image dates, timeliness of data, ground truth and sampling procedures.

Interpreting LANDSAT Color Composite Imagery

Image interpretation requires a complex mixture of artistic, scientific and physical abilities. Some basic techniques can be learned from textbooks and lectures but interpretation is primarily learned through experience. This section of the guide does not attempt to teach image interpretation but rather presents some suggestions and tips on how to approach the interpretation task. A descriptive key is also provided to help the user in developing an approach.

The successful interpretation of LANDSAT imagery requires that the user make accurate associations between a particular land cover type and its representative color tone, pattern, shape, areal extent and location on the image. Several key factors determine the user's ability to see, comprehend, and synthesize the above variables and then make inferences about them that are accurate and consistent.

ROW CROP

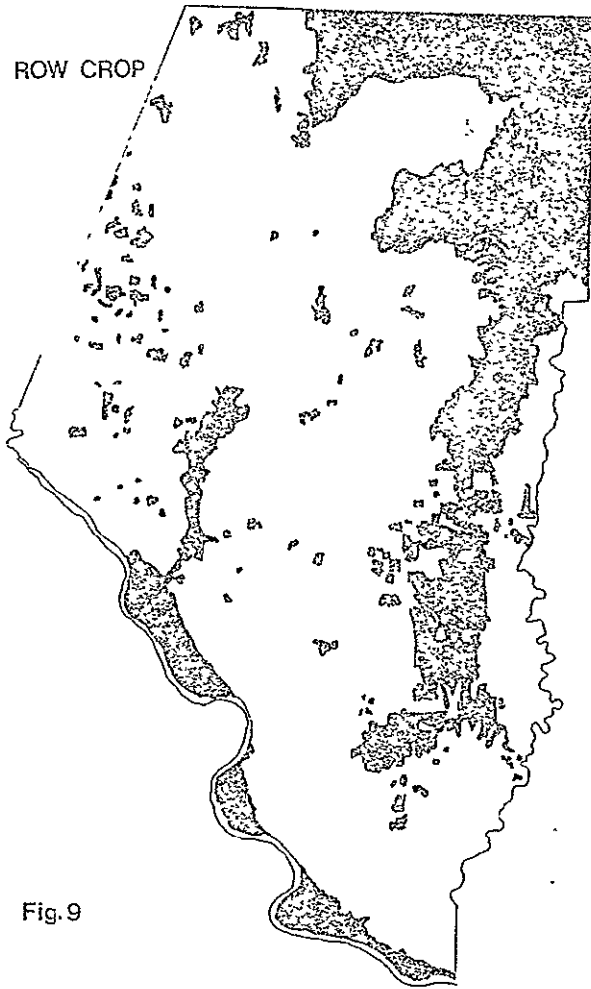


Fig. 9

PASTURE

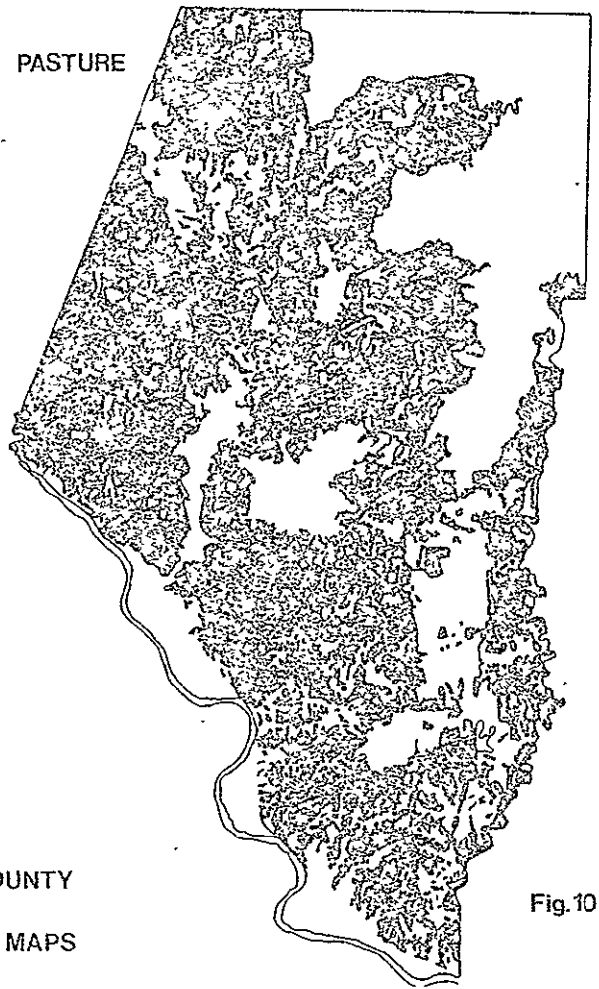


Fig. 10

BOONE COUNTY
DETAILED MAPS

ORIGINAL PAGE IS
OF POOR QUALITY

FOREST



Fig. 11

URBAN

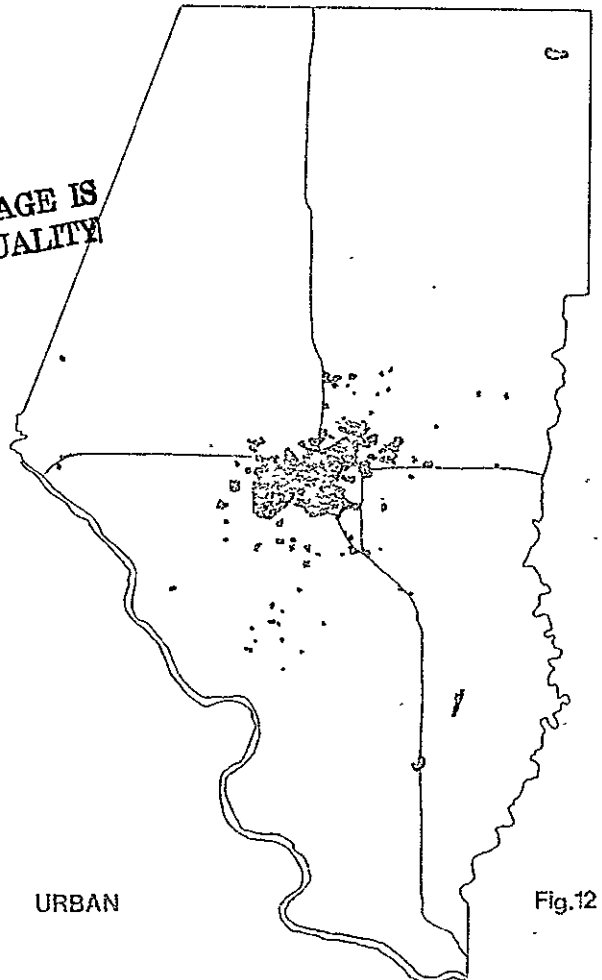


Fig. 12

ROW CROP

PASTURE

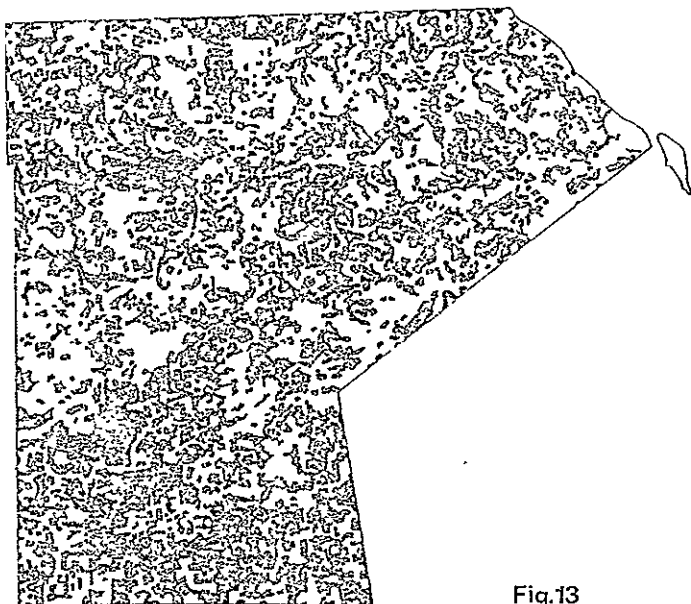


Fig.13

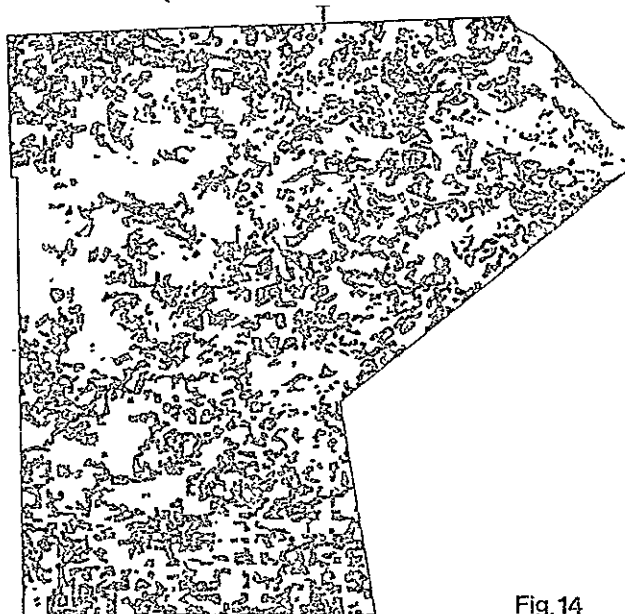


Fig.14

FOREST

ORIGINAL PAGE IS
OF POOR QUALITY

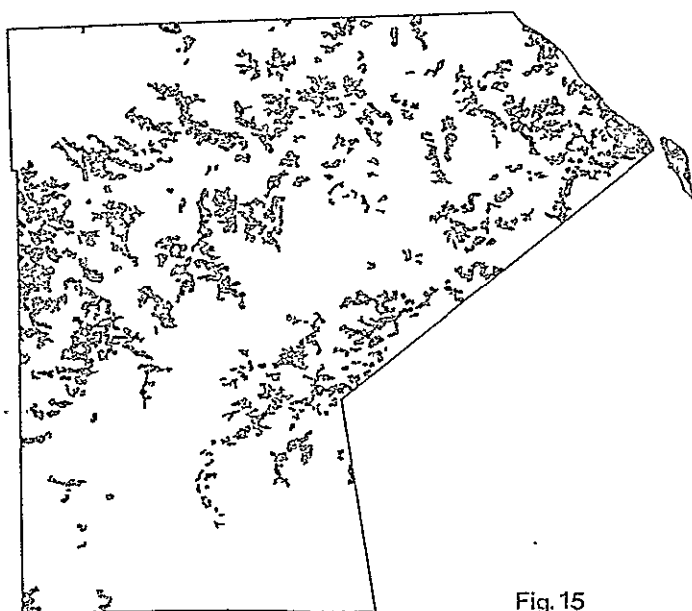


Fig.15

RALLS COUNTY

DETAILED MAPS

These factors are:

1. The user's knowledge base is the most critical determinant in what the user can or cannot see on the image. One literally "sees what one knows." A previous study revealed that geologists and foresters were better at interpreting physical landscape features than agronomists who were more competent in interpreting agricultural features such as cropping and soil patterns. Geographers were best at interpreting cultural features and seeing the overall land cover relationships.
2. The user must develop the ability to consistently separate color tones with his eyes and keep them separated in his or her mind. This ability is further refined through practice in the mapping task.
3. The interpreter very seldom has to identify objects because of the low resolution of satellite images. The interpreter must infer a land use or a land cover type from clues even less specific than those relied upon in the interpretation of aerial photography. An ability to interpret on aerial photography does not guarantee that one will be successful in interpreting categories on a satellite image.

Three Interpretation Approaches. Three methods for the interpretation task were used. Each technique or method relies upon the satellite image as the primary data source but will vary in the degree to which the approach depends upon aerial photography.

The first method requires the user to map solely from satellite imagery without referring to any type of supporting aerial photography. (See Figure 16) The user first establishes the basic relationships between color tones and land cover categories utilizing descriptive keys, ASCS index photos and other supportive background information. The aerial photography is then put aside and interpretation done strictly from the satellite image.

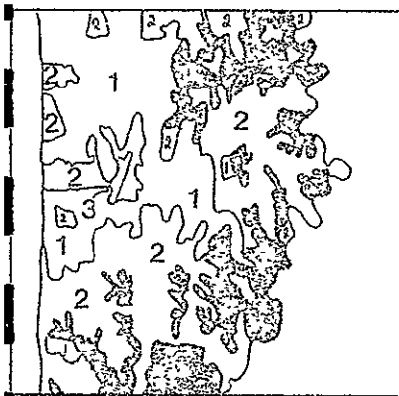
This technique is the fastest and the cheapest approach. It produces a map with fewer categories and will likely have a higher accuracy than other techniques. This method is also easier for the user who is familiar with the area being mapped. An interpreter with a high degree of confidence in his interpretive ability will also do well with this method.

The second method utilizes aerial photography as a guide throughout the interpretation process. The user consults the supporting information to get an idea of what type of land cover should be recognized on the corresponding area of the satellite image. The support photography is consulted each time a new area is mapped but the inferences are based primarily on what is seen on the imagery. (See Table 2) This technique works best for the users who lack confidence in their interpretation abilities. As the user gains more experience, he or she will probably switch to one of the other approaches.

Figure 16

SAMPLE MAP PRODUCTS

ORIGINAL PAGE IS
OF POOR QUALITY



-  FOREST
- 1 ROW CROP
- 2 PASTURE
- 3 URBAN

METHOD 1



-  FOREST
- 1 DISTURBED
- 2 PASTURE
- 3 URBAN

ST. FRANCOIS CO.



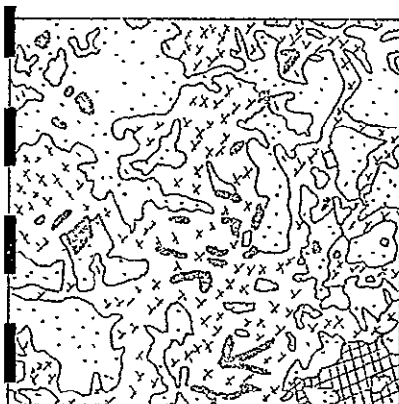
-  WATER
-  ROW CROP
-  WHEAT
-  PASTURE
-  FOREST
-  URBAN

METHOD 2



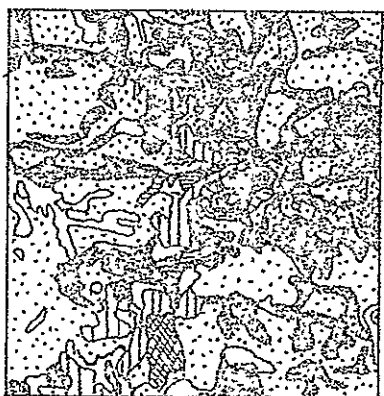
-  DISTURBED
-  PASTURE
-  ROW CROP
-  FOREST

RALLS CO.



-  SHRUB/PASTURE
-  FOREST
-  PASTURE
-  DISTURBED
-  URBAN

METHOD 3



-  PASTURE
-  FOREST
-  RECENTLY CLEARED
-  FOREST TO PASTURE
-  FOREST TO ROWCROP
-  ROW CROP
-  DISTURBED

PHELPS CO.

DENT CO.

TABLE 2

TYPES OF SUPPORT PHOTOGRAPHY AVAILABLE

<u>Source</u>	<u>Film Type</u>	<u>Scale</u>	<u>Photo Index Sheets Available</u>	<u>Enlargements Available</u>
NASA / SKYLAB	Black and White Color Color Infrared	1:2,850,000 (S190A) 1:950,000 (S190B)	No	Yes
NASA / High Altitude Aircraft	Black and White Color Color Infrared	1:125,000	No	Yes
USGS / Aerial Mapping Photography	Black and White	1:17,000 - 1:90,000	Yes	Yes
SCS (Soil Conservation Service)	Black and White	1:40,000 1:48,000	Yes	Yes
ASCS (Agricultural Stabili- zation and Conservation Service)	Black and White	1:10,000 - 1:40,000	Yes	Yes

Note: For additional information on sources of aerial photography, its extent of coverage and how it can be ordered, consult the Index to Aerial and Space Photographic Coverage of Missouri (Barney and Johannsen, 1976). Copies can be obtained by writing to the Extension Publications Office, 205 Whitten Hall, University of Missouri, Columbia, Missouri 65201, for \$3 per copy.

The third method relies heavily on supporting aerial photography as a reference for evaluating what is seen on the satellite image. The user interprets a portion of the study area and compares the interpretation to the same area on the support photography. The user must reevaluate the interpretation based on what is seen on the supporting photography and assign the area to a particular category. This technique is good for documenting changes in land use and cover type over time. An area categorized as pasture in either of two preceding techniques may be more accurately identified as an area recently converted from timber to pasture.

The latter method is the most time consuming of the three approaches. Previous photo interpretation experience is helpful with this approach. The user must avoid simply transferring data from the supporting aerial photography to the satellite image since this would defeat the purpose of the interpretive task and would add to costs. One must note that the photography is consulted after the image has been interpreted.

Interpretation Tips.

1. Use a "logical search" method of interpretation. Isolate the variables (color tone, pattern, etc.) that represent a particular land cover category and delineate all the areas with similar characteristics. Follow this procedure for each category in the classification system.
2. Always develop a generalized map first. An immediate attempt at mapping in detail usually leads to frustration and failure to accomplish the mapping task in a satisfactory manner.
3. Interpret only when full concentration can be given to the task. Interpreting on a regular schedule seems to give more consistent and reliable results. Select the time of day when you are most alert.
4. Limit the interpretation time to $1\frac{1}{2}$ to 2 hours in order to avoid fatigue and loss of concentration.
5. If more than one image is required to cover the study area, try to obtain coverage of similar dates. One becomes accustomed to working with a particular set of color tones and the transition is easier if the dates are similar. Be aware that images taken on the same date or two days apart may have different color tones due to differences in processing.
6. An image of poor quality cannot be interpreted accurately and should be returned. When ordering a color composite, select those scenes with the highest quality band rating. All LANDSAT imagery enlarged to 1:250,000 scale will exhibit scan lines across the image. The scan lines will appear faint, white, closely spaced horizontal lines running across the entire scene. Consult Appendix III for specific information on how and where to order imagery.

7. The season of the year is important when selecting a satellite image. The selection should be based upon the categories which the user wants to differentiate. Select the season when there is maximum contrast of these categories. Suggested time periods for most Level I categories are Spring and/or Fall.

Interpretation Keys. There are certain color tones, patterns, shapes and location factors which give clues to the interpretation of a specific land use or color type. This section provides some helpful information on recognizing these different categories.

1. Urban/built-up land

Spring: Medium blue tinged with white.

Fall: Light blue to dark blue gray.

Urban and built-up areas appear as circular to irregular shapes on the LANDSAT image. Urban areas tend to reflect the shape of their central business districts (CBD). The denser concentration of structures and roads found in the CBD along with the absence of vegetation reflect light of a greater intensity than the more mixed land uses surrounding the core area.

Strip development is easy to spot since it will appear as bluish white strips along major transportation routes. Highways appear as narrow white lines. Interstates are wider and therefore easier to recognize. Street networks in larger urban areas can be recognized by the typical grided pattern.

Away from the CBD, older residential and less concentrated commercial areas fade from blue to shades of pink or red indicating an increase in vegetative cover. These areas can often be inferred on the basis of their location within the urban area and not on the basis of image characteristics.

More isolated built-up areas like large shopping centers and large housing developments will contrast sharply with their surroundings. Shopping centers will appear as rectangular bluish areas fringed with white. Large new housing developments appear as organized blocks and will sometimes be faintly tinged with blue.

Small subdivisions, trailer parks and similar developments will appear as small white rectangles or circular areas but will usually be inferred by their locations. One must remember that the resolution of the LANDSAT image is greater than one acre in size.

2. Agricultural land

Spring: Row crop land will appear as bare soil and range in color from white to gray to black depending upon soil type and moisture content. Winter wheat will be bright red while pastures will appear as light pink or light red.

Fall: Row crops will appear as a greenish color fading to almost white. Plowed fields will appear similar as spring but will usually be lighter in color since surface moisture content is likely to be lower. Pasture areas will appear light pink but will increase the red intensity as fall growth continues.

Except for areas of bare soil (fall plowed, winter fallow, spring plowed) a color composite will tend to indicate land as various pinks and/or light red hues. Timber will almost always be a deeper red and contrast with agricultural land. In early spring, late fall and winter, timber will appear as greenish brown and make a vivid contrast with surrounding pastures.

Pattern and texture are significant for interpretation in agricultural lands since they will appear as regular geometric orders characteristic of mans activity. Fields will be rectangular in flat to gently rolling terrain. In more rugged landscapes, field boundaries will often parallel the contour of the land.

Cropped areas will be found along drainage systems in rougher terrain and give way to pasture as distance increases from the stream or river. Timber and brush areas will have more irregular patterns and have a more non-uniform texture than agricultural land.

Crop land is best separated from pasture when bare soil is at a maximum (early spring and late fall). In summer images, pastures on rougher terrain will tend to be less vigorous than crops (crop land will be darker red or pink). As crops mature, they will reflect less in the infrared portion of the spectrum and contrast more with the pasture.

3. Forest

Early spring: Greenish brown

Fall: Dark red to greenish brown

With a color composite, the color tone of forested land will vary greatly because of the time of year. From late spring through mid-fall, they will appear in varying shades of deep red tones. Mixed forest in the fall to winter transition will appear as numerous shades of light red. After the forests have lost their leaf cover, the tones will change to various shades of brown.

LANDSAT imagery has a low resolution which usually precludes texture as an image characteristic in differentiating forest lands. At times, however, a "rough" texture can be associated with timber on images of exceptionally high quality. The type of timber is not usually interpretable from LANDSAT imagery. However, a comparison of winter and summer images can reveal the differences between conifers and deciduous timber stands. Also, conifers will tend to exhibit purple-red colors when in nearly pure stands.

4. Water

A LANDSAT color composite will show clear water as black. Turbidity, however, will greatly change the spectral characteristics of water.. Increasing turbidity will show up as lighter shades of blue. Water with heavy sediment loads will appear nearly white in color. Bodies of water will appear in a variety of shapes. Streams, however, will be identified by their characteristic dendritic or controlled form of patterns.

5. Wetlands

Wetlands will appear as shades of blue on a color composite. A great deal of inference must be used based on soils and hydrology of the area. Forested wetlands may appear as a mix of timber overlying water bodies or may appear as a wet soil.

6. Barren land

Barren land in Missouri will usually be disturbed lands due to mining and will appear as light blue to white. This category will appear very similar to the spectral responses from urban and built-up areas. The geographical location will be a great aid in separating these categories. Reclaimed land will appear similar to pasture.

APPENDIX I

STANDARD MAP PRODUCTS AVAILABLE TO MISSOURI USERS

Source:

- I. Missouri's Department of Natural Resources
 Division of Geology and Land Survey
 P. O. Box 250
 Rolla, Missouri 65401
 314-364-1752

<u>Product</u>	<u>Scale</u>	<u>Cost</u>
Topographic maps		
7.5 minute series	1:24,000	\$0.75 each
15 minute series	1:62,500	\$0.75 each
1:250,000 series	1:250,000 or	\$1.00 each
17 sheets	1" = 8 mi	
Topographic maps of Missouri	1" = 8 mi	\$2.00 each
200' Small contour interval		
1971. 1 sheet		
Index Map of published	1:1,000,000	No charge
topographic sheets		
Base maps		
Base map of Missouri	1" = 8 miles	\$1.00 each
1971. 1 sheet		
Base map of Missouri	1" = 2 miles	\$0.50 each
14 sheets		

- II. Missouri State Highway Department
 c/o Survey and Plans
 3025 E. Kearney
 Jefferson City, Missouri 65101

<u>Products</u>	<u>Scale</u>	<u>Cost</u>
County highway map	1" = 1 mile	\$1.00 each
Blue Print		
County highway map	$\frac{1}{2}$ " = 1 mile	\$0.15 each
Black and White		\$15.00 per set

III. Mid-Continent Mapping Center
U. S. Geological Survey
Rolla, Missouri 65401

<u>Products</u>	<u>Scale</u>	<u>Cost</u>
Orthophotoquads*		
Diazo Paper	1:24,000	\$1.25 each
Half tone image on photographic paper	1:24,000	\$6.50 each
Half tone image on opaque scale-stable film	1:24,000	\$10.00 each

* Only available for a limited number of quadrangles as of January, 1977.

APPENDIX II

THE LANDSAT SYSTEM

In July, 1972, the National Aeronautics and Space Administration (NASA) launched LANDSAT-1, formerly called ERTS-1. In January, 1975, LANDSAT-2 which is nearly identical to LANDSAT-1 was put into orbit.

Both satellites circle the earth in what are called "sunsynchronous orbits." The movements of the satellites are synchronized with the earth's rotation and its orbit around the sun thus keeping the plane in which the satellites orbit at a constant angle to the earth - sun line. This orbital pattern provides fairly constant sunlight conditions for all the imagery acquired and reduces major differences in sunlight conditions to seasonal variations in sunlight.

Moving from north to south at an altitude of 570 miles, each satellite orbits the earth 14 times a day between 80 degrees north and south latitude. On each orbit the satellite's sensors image a strip 115 miles wide as the spacecraft crosses the sunlit side of the earth. It takes each satellite 18 days to image the entire earth. With both satellites in operation, their timing is such that complete global coverage occurs every 9 days.

Each day the planes in which the satellites orbit move westward 1 degree of longitude or 105 miles. Missouri is completely imaged by one satellite over a 5 day period. (See Figure II-1) On the first day the St. Louis area and the Bootheel are covered. Rolla is imaged on the second day as the orbit moves westward. Columbia is imaged on the third day. The orbit brings the satellite over Kansas City on the fourth day. On the fifth day, the extreme northwest corner of the state is covered. The 18th day in the cycle brings the spacecraft over the St. Louis area again.

SENSING SYSTEMS

Each LANDSAT satellite carries two earth sensing systems - a four band multispectral scanner (MSS) and a television or return beam vidicon (RBV) system. The largest amounts of usable data have been collected by the MSS systems. (See Table II-1) The RBV system is of secondary importance and therefore will briefly be described.

MSS SYSTEM

Each 115 mile wide strip imaged by the satellites is divided into equally sized units called "scenes." All LANDSAT scenes are 115 miles x 115 miles or 13,225 square miles in area. Each scene is imaged in four different wavelength bands of light (See Table II-2).

The MSS is a line scanning device. Using a mirror it scans back and forth across the earth's surface along lines perpendicular to the satellites path. At any instant in time, the mirror is capturing reflected light from an area 260 ft. in diameter and 1.1 acres in area. This area is called an "instantaneous field of view." There are $7\frac{1}{2}$ to 8 million instantaneous fields of view making up each LANDSAT scene. (See Figure II-2)

Figure 11-1

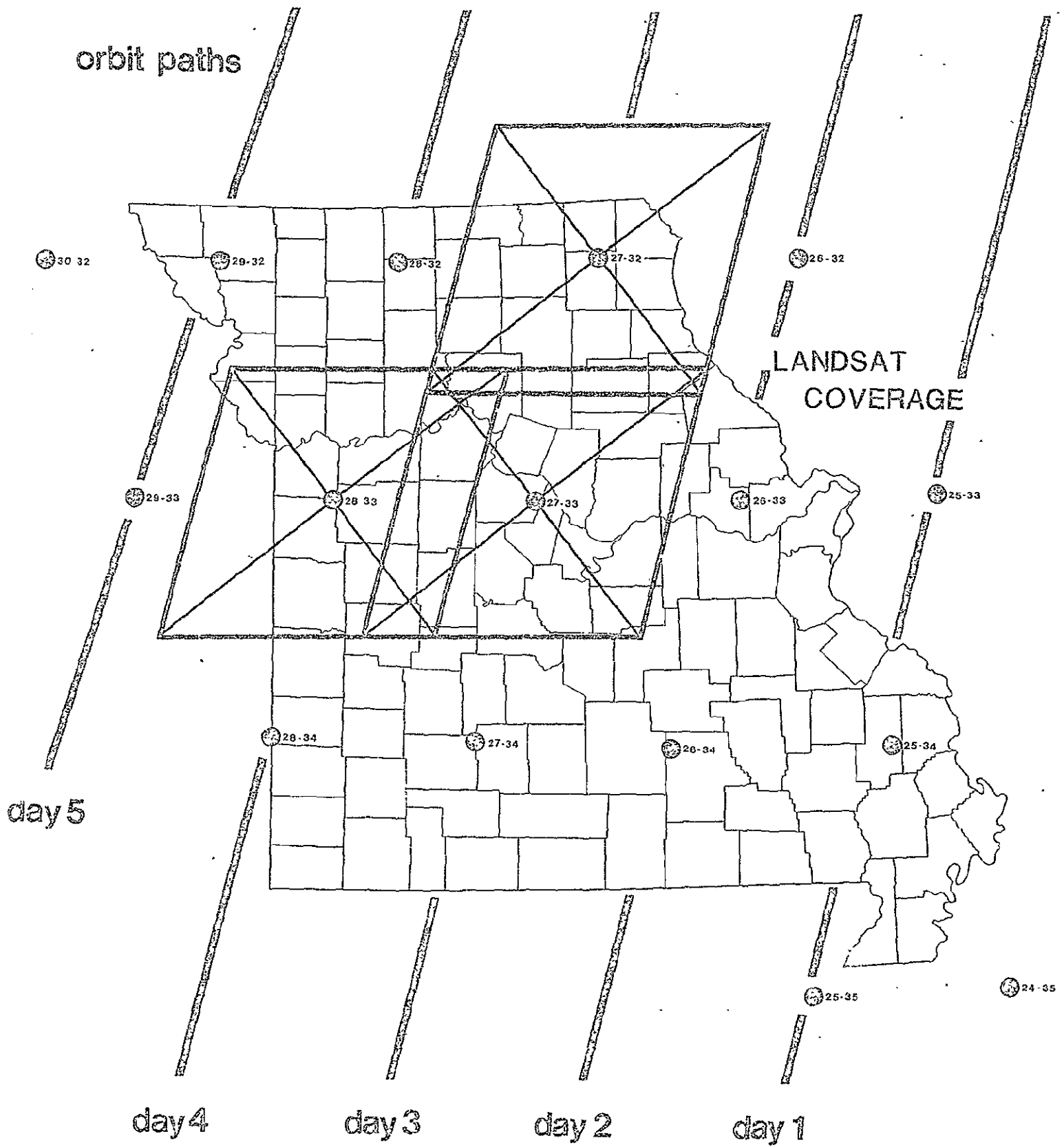


TABLE II-1 LANDSAT OPERATIONAL STATISTICS AS OF JULY, 1976

	<u>Landsat 1</u>	<u>Landsat 2</u>
MSS: Number of orbits	20,342	7,609
Total scenes imaged (U.S. Acquisition Station)*	142,559	57,169
Real time images	95,596	21,967
Recorded images	46,963	35,202
Total scenes imaged (Foreign Acquisition Stations)	98,414	32,784
Canada	41,834	24,620
Brazil	29,822	1,550
Italy	26,758	6,614
RBV: Total scenes imaged (U.S. Acquisition Stations)	1,546	1,444
Real time images	727	1,193
Recorded images	819	251
Total scenes imaged (Foreign Acquisition Stations)	144	227
Canada	144	36
Brazil	0	193
Italy	0	0

*U.S. receiving stations are: Goddard Space Center, Greenbelt, MD.; Goldstone, California; Fairbanks, Alaska. These stations perform all the telemetry, tracking and command functions for both satellites.

Source: LANDSAT News Letter No. 11 Oct. 1, 1976.

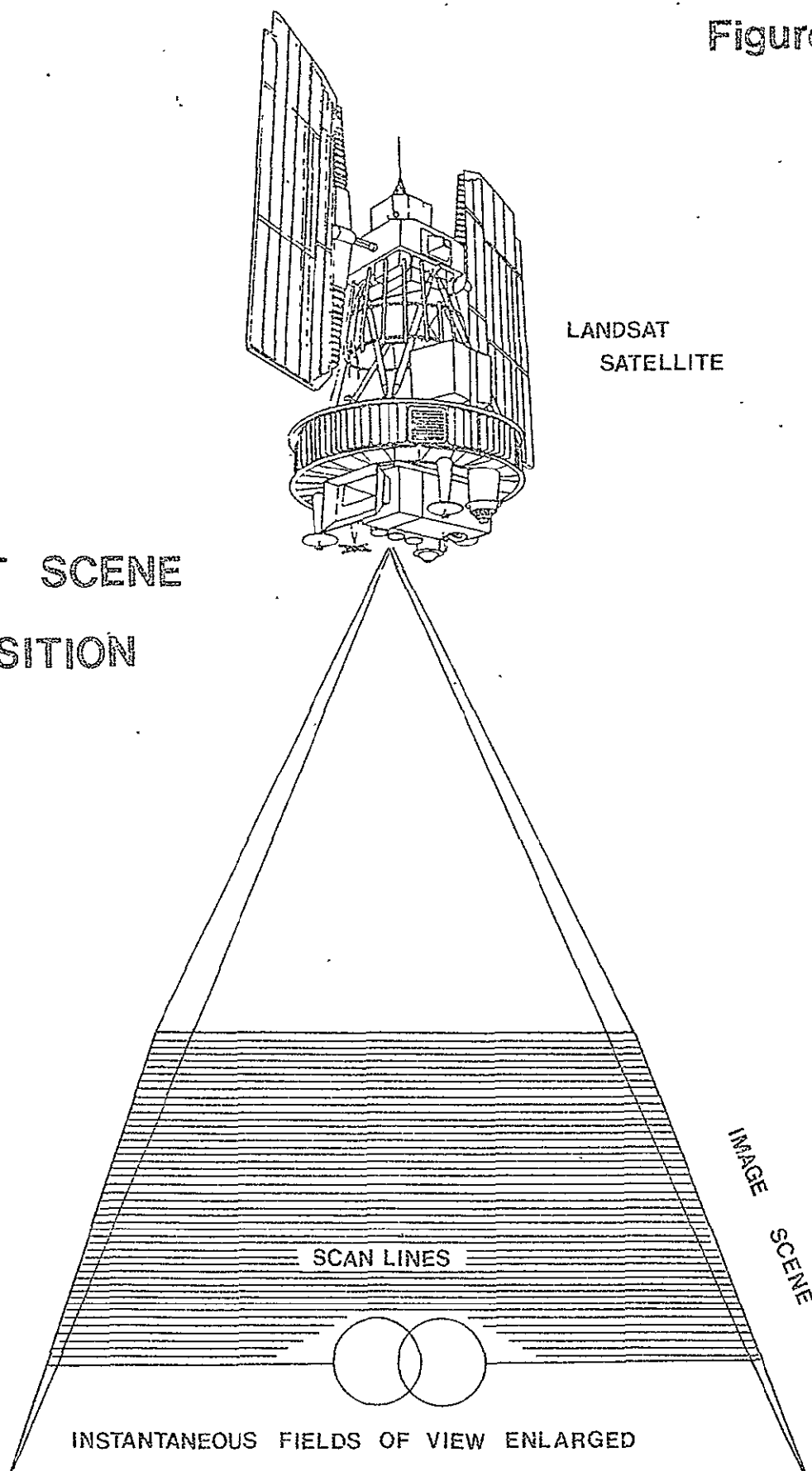
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TABLE II-2 SPECTRAL CHARACTERISTICS OF THE LANDSAT MSS

<u>Band</u>	<u>Spectral Range (Wavelength)</u>	<u>Spectral Range (Color)</u>	<u>General Land Use and Land Cover Applications</u>
4	.5 - .6 Micrometers	Green	Fair contrast between vegetation and soil. Emphasizes sediment laden water and shallow water.
5	.6 - .7 Micrometers	Lower Red	Maximum contrast for geology, topographic and cultural features.
6	.7 - .8 Micrometers	Upper Red to Near Infrared	Good land - water contrast. Vegetation emphasized
7	.8 - .11 Micrometers	Near Infrared	Best penetration of atmospheric haze. Best for land - water discrimi- nation.

Figure II-2

LANDSAT SCENE
COMPOSITION



The intensity of light reflected by each instantaneous field of view is recorded on an array of detectors, each sensitive to one of the wavelength bands of light outlined in Table II-2.

The intensity of the reflected light is recorded by converting it into numerical values ranging from 0 to 63. This numerical value is called a picture element or "PIXEL." A pixel is recorded for each instantaneous field of view in each of the 4 wavelength bands for a total of 32 million pixels per LANDSAT scene. It takes the scanner approximately 25 seconds to record one scene.

The recorded data is handled in one of two ways as it is collected. If the satellite is within range of a receiving station the data can be directly transmitted by radio. Data collected beyond the range of a receiving station is tape recorded for delayed transmission.

Once received, the data can be kept in a digital mode for computer processing or reproduced photographically. The graphic process involves converting the numerical values of selected pixels into corresponding shades of grey on a 64 level grey scale. The end products for each scene are 4 grey (black and white) images, each showing the relative intensity of light reflected from the earth's surface in a specific wavelength band. The color composites, more accurately referred to as false-color composites are made by combining three of the four grey images. The grey images are exposed through colored filters onto color film. Bands 4, 5 and 7 are most frequently used for this purpose. The human eye is sensitive to the infrared region of the spectrum represented by band 7 so it is filtered with a color the eye can detect. The end product is called a false-color composite because some of the colors do not represent the true spectral colors of the areas imaged.

SPATIAL RESOLUTION

LANDSAT imagery has a low resolution capability when compared to conventional aerial photography (See Table II-3). The distinct boundaries between various land uses visible on aerial photographs are not found on the LANDSAT images. The resolution capability of the scanning system reflects a compromise made between the need for good spatial resolution and the need for large area coverage. Also taken into account in the compromise is the orbital pattern of the spacecraft and the spectral resolution capabilities of the scanner.

The LANDSAT image is an "averaged" representation of what one actually sees on the earth's surface. Each instantaneous field of view is recorded as one response in four different wavelength bands. The light reflected by any object or area (less than 260 feet in diameter) is averaged with the reflection from adjacent objects or areas within the instantaneous field of view and recorded as one response. An area of 1.1 acres is sufficiently large to encompass a number of different objects or land cover types and the averaged response may not be a true representation of any of them. Only instantaneous fields of view taking in uniform, homogeneous areas are truly representative of what is actually there. Linear features like roads, bridges, power lines, airport runways, etc., which are often less than 260 feet in diameter, can be seen if their averaged response is extremely high and there is good background

TABLE II-3 RESOLUTION COMPARISONS

<u>Source</u>	<u>Altitude</u>	<u>Scale</u>	<u>Ground Resolution</u>
LANDSAT	570 mi.	1:3,360,000	Low Contrast 100 - 250 M Medium Contrast 30 - 100 M High Contrast Linear Features 15 - 30 M
SKYLAB	270 mi.	S190A 1:2,800,000 S190B 1:950,000	40 M - 80 M 17 M - 30 M
NASA High Altitude Aircraft Photography	12 mi.	1:120,000	15' - 30'
Medium Altitude Aircraft Coverage			
USGS Orthophotography	40,000'	1:80,000	15' - 25'
SCS	20,000'	1:40,000	10' - 15'
ASCS	10,000'+	1:20,000+	4' - 10'
Low Altitude Coverage	10,000'	1:20,000'	1' - 3'

contrast. For example, a highway can often be seen quite easily where it cuts through a heavy forested area, over a water body or across an open, grassy area and then it will fade from view as it goes into an urban or built-up area that offers less contrast.

RBV SYSTEM

The return beam vidicon system consists of three television cameras that simultaneously image the earth in three wavelength bands (See Table I-4). An electrical failure aboard LANDSAT-1 rendered the RBV system inoperative shortly after launch. All subsequent data from LANDSAT-1 has been collected by the MSS system. Limited amounts of RBV imagery are available from LANDSAT-2.

The RBV cameras view approximately the same scene as the MSS. Each RBV image covers 100 x 100 nautical miles and is reproduced as a black and white photographic positive. RBV images can also be reproduced as color composites. The spectral wavelength bands are similar to those of the MSS but the instantaneously acquired RBV images have a high degree of geometric fidelity.

TABLE II-4 RBV SPECTRAL WAVELENGTH BANDS

Band	Spectral Range (Wavelength)	Spectral Range (Color)
1	.46 - .60 Micrometers	Green
2	.56 - .68 Micrometers	—Red
3	.66 - .82 Micrometers	Lower Red - Near Infrared

APPENDIX III

HOW TO ORDER LANDSAT IMAGERY

LANDSAT imagery is available to the public through the U.S. Department of the Interior's Earth Resources Observation Systems (EROS) Data Center. Orders can be placed directly with the Data Center or through the National Cartographic Information Center's (NCIC) User Services Center located at the USGS Mid-Continent Mapping Center in Rolla, Missouri.

Direct orders through EROS.

Write: EROS Data Center
Sioux Falls, South Dakota 57198

Phone: 605-594-6511, Ext. 151

There are several methods available to the user for determining availability of images for a specific geographical area and placing an order.

METHOD 1 - Consult Figure III-1 and select the nominal center (described by a path and row number) closest to the area of interest. Write or phone the Data Center and request a computer listing of available imagery for the nominal center selected. Specify the year and time of year or specific dates of interest. The computer listing (See Figure III-1) will contain all the information necessary for ordering specific images and will be accompanied by an order form. (See Figure III-2)

METHOD 2 - Write or phone the Data Center and request a geographic computer search form. (See Figure III-3) Complete and return the form. A computer listing will be sent describing available imagery over the user's area of interest along with the appropriate order form.

Ordering through NCIC

Write: Mid-Continent Mapping Center
U.S. Geological Survey
NCIC User Center
Rolla, Missouri 65401

Phone: 314-364-3680

The NCIC User Services Center contains a browse file of LANDSAT imagery, SKYLAB photography, NASA aircraft photography and other aerial mapping photography. The purpose of the NCIC User Center is to provide a place for users to view the different images and photography mentioned above. This information is on 16 mm microfilm cassettes and is easily viewed on a microfilm reader. Personnel at the user center are available to provide assistance in viewing and selecting images.

The Center is linked to the computer at the EROS Data Center. A user can request a listing of the imagery over a specific area and receive an identical listing as mentioned above specifying the available imagery over the area desired. The listing identifies the cassette on which the imagery is stored. The user can then select the appropriate cassette and view the frames of interest on the microfilm reader. If the imagery meets the users specifications, an order can be given to the personnel at the User Center which would be transmitted directly to the EROS Data Center. The EROS Data Center would mail the order directly to the user.

Figure III-4 lists EROS Data Center prices as of 1 January, 1977.

1

173 ACCESSIONS

TYPE	COVERAGE	FILM SOURCE	PHOTO/SCENE ID	QUAL	CLD	DATE	CENTER/1ST FRAME	CTR	SCALE	ALT	OLAP
------	----------	-------------	----------------	------	-----	------	------------------	-----	-------	-----	------

ERTS-2 (MSS) B&W-02.2" 82067160005N000 5888 10% 750330 N37 33 59 W090 08 59 3369000 9057 10%
SCENE (N38 09 15, W088 52 56)(N38 28 17, W090 53 18)(N36 39 25, W089 25 50)(N36 57 59, W091 23 54) S

ERTS-2 (MSS) 9&W-02.2" 821751559550000 5885 10% 750716 N37 33 59 W090 13 59 3369000 9085 10%
SCENE (N38 09 13, W088 57 15) (N38 28 24, W090 57 58) (N36 39 18, W089 31 10) (N36 58 00, W091 29 35) C

ERTS-2 (MSS) B&W-C2.2" 82247155845000 5885 10Z 750926 N37 22 59 W090 12 59 3369000 9228 10Z
SCENE (N37 59 10, W088 55 33)(N38 18 00, W090 58 02)(N36 27 41, W089 29 07)(N36 46 02, W091 29 14) S

ERTS-1 (MSS) B&W-02.2" 85025155115A000 5888 10% 750514 N37 21 59 W090 30 00 3369000 9217 10%
SCENE (N37 58 33, W089 12 38)(N38 16 33, W091 15 09)(N36 27 08, W089 46 00)(N36 44 39, W091 46 09)

ERTS-1 (MSS) 83W-02.2" 85223153935000 5858 00% 751128 N37 30 00 W090 20 59 3369000 9076 10%
SCENE (N38 06 07, W089 05 06) (N38 23 45, W091 05 58) (N36 35 56, W089 37 10) (N36 53 06, W091 35 42) C

```

-----
ERTS-1 (MSS)      B&W-02.2" 852591537150300 8885 10% 760103 N37 21 59 W090 19 59 3369000 9141 10%
SCENE (N37 58 06, W089 03 29) (N38 16 19, W091 04 53) (N36 27 23, W089 36 16) (N36 45 07, W091 35 20) S
-----

```

ERTS-2 (MSS) B&W-C2.2" 823731557250000 8888 10% 760130 N37 18 59 W090 22 59 3369000 9211 10%
SCENE (N37 54 59, W089 05 40) (N38 13 59, W091 07 46) (N36 23 43, W089 39 23) (N36 42 13, W091 39 08)

```
ERTS-1 (MSS) B&W-02.2" 85295153455C000 5888 00% 760208 N37 22 59 W090 20 59 3369000 9217 10%
SCENE (N37 59 16, W089 03 45) (N38 17 51, W091 06 08) (N36 27 50, W089 37 01) (N36 45 56, W091 37 03)
```

ERTS-1 (MSS) B&W-72.2" 85313153345C000 8888 10% 760226 N37 30 00 W090 22 59 3369000 9187 10%
SCENE (N38 06 29,W089 06 38)(N38 24 28,W091 08 27)(N36 35 13,W089 38 43)(N36 52 44,W091 38 39)

ERTS-1 (MSS) 8&W-02.2" 853851528550000 8888 00% 760508 N37 25 59 W090 30 59 3369000 9122 10%
SCENE (N38 02 28, W089 14 55) (N38 19 56, W091 16 21) (N36 31 45, W089 46 48) (N36 48 45, W091 45 53)

TOTALS ERTS- 173, MANNED SPACECRAFT- , NASA-AIRCRAFT- , AERIAL MAPPING-

FIGURE 1

SAMPLE COMPUTER LISTING

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OF POOR QUALITY

Phone: (609) 691-1511
TTS: 609/691-0151



Date _____

NAME (LAST) _____ (FIRST) _____ (INITIAL) _____ Previous Contact No. _____
(IF KNOWN)

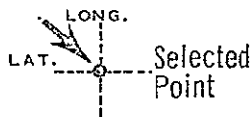
CITY _____ Phone: (BUSINESS) _____

STATE _____ ZIP _____ Phone: (HOME) _____

Your Reference No. _____
(FOR GOVT. ACCT. OR OTHER)

TO INITIATE AN INQUIRY AND COMPUTER GEOSearch, COMPLETE ONE OF THE FOLLOWING

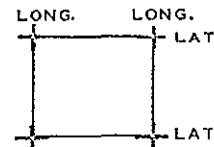
POINT SEARCH



Imagery with any coverage over the
selected point will be included.

Latitude _____
Longitude _____

AREA RECTANGLE



Imagery with any coverage over the
selected area will be included.

Latitude _____ to Latitude _____
Longitude _____ to Longitude _____

GEOGRAPHIC NAME AND LOCATION (INCLUDE A MAP IF POSSIBLE) _____

INDICATE YOUR INTERESTS FOR EACH OF THE FOLLOWING:

TYPE OF COVERAGE

- ☐ LANDSAT
- ☐ SKYLAB
- ☐ NASA-AIRCRAFT
- ☐ AERIAL MAPPING PHOTOGRAPHY

TIME OF YEAR

- ☐ JAN-MAR
- ☐ APR-JUNE
- ☐ JULY-SEPT
- ☐ OCT-DEC
- ☐ SPECIFIC DATES _____

TYPE OF PRODUCT

- ☐ BLACK & WHITE
- ☐ COLOR OR
COLOR INFRARED

MAXIMUM CLOUD COVER ACCEPTABLE

☐ 10% ☐ 30% ☐ 50% ☐ 80% ☐ 100%

MINIMUM QUALITY RATING ACCEPTABLE

☐ 0-2 ☐ 3-4 ☐ 5-6 ☐ 7-9
(VERY POOR) (POOR) (FAIR) (GOOD)

APPLICATION AND INTENDED USE _____

FIGURE III-3

FIGURE 111-4A



PRICE LIST
STANDARD REMOTE SENSING DATA
 U. S. DEPARTMENT OF THE INTERIOR
 GEOLOGICAL SURVEY



JANUARY 1, 1977

SATELLITE DATA

STANDARD LANDSAT			BLACK and WHITE		COLOR	
IMAGE SIZE	NOMINAL SCALE	PRODUCT FORMAT	UNIT PRICE	PRODUCT CODE	UNIT PRICE	PRODUCT CODE
55.8mm (2.2 in.)	1:3359000	Film Positive	\$8.00	11		
55.8mm (2.2 in.)	1:3359000	Film Negative	10.00	01		
18.5cm (7.3 in.)	1:1000000	Paper	8.00	23	\$12.00	63
18.5cm (7.3 in.)	1:1000000	Film Positive	10.00	13	16.00	53
18.5cm (7.3 in.)	1:1000000	Film Negative	10.00	03		
37.1cm (14.6 in.)	1:500000	Paper	12.00	24	25.00	64
74.2cm (29.2 in.)	1:250000	Paper	20.00	26	50.00	66
COLOR COMPOSITE GENERATION					50.00	59
NOTE: 1) Portrayed in false color (infrared) and not true color 2) Cost of product from this composite must be added to total cost						
COMPUTER COMPATIBLE TAPES (CCT)						
TRACKS	b p i.	FORMAT	SET PRICE		PRODUCT CODE	
7	800	Tape Set	\$200.00		82	
9	800	Tape Set	200.00		83	
9	1600	Tape Set	200.00		84	

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MANNED SPACECRAFT DATA

SKYLAB S190A			BLACK and WHITE		COLOR	
IMAGE SIZE	NOMINAL SCALE	PRODUCT FORMAT	UNIT PRICE	PRODUCT CODE	UNIT PRICE	PRODUCT CODE
55.8mm (2.2 in.)	1:2850000	Film Positive	\$ 8.00	11	\$10.00	51
55.8mm (2.2 in.)	1:2850000	Film Negative	10.00	01		
18.3cm (6.4 in.)	1:1000000	Paper	8.00	23	12.00	63
32.5cm (12.8 in.)	1:500000	Paper	12.00	24	25.00	64
65.0cm (25.6 in.)	1:250000	Paper	20.00	26	50.00	66
SKYLAB S190B						
			BLACK and WHITE		COLOR	
IMAGE SIZE	NOMINAL SCALE	PRODUCT FORMAT	UNIT PRICE	PRODUCT CODE	UNIT PRICE	PRODUCT CODE
11.4cm (4.5 in.)	1:950000	Paper	\$ 6.00	22	\$ 8.00	62
11.4cm (4.5 in.)	1:950000	Film Positive	8.00	12	12.00	52
11.4cm (4.5 in.)	1:950000	Film Negative	10.00	02		
21.8cm (8.6 in.)	1:500000	Paper	8.00	23	12.00	63
43.4cm (17.1 in.)	1:250000	Paper	12.00	24	25.00	64
86.8cm (34.2 in.)	1:25000	Paper	20.00	26	50.00	66
APOLLO/GEMINI						
			BLACK and WHITE		COLOR	
IMAGE SIZE	NOMINAL SCALE	PRODUCT FORMAT	UNIT PRICE	PRODUCT CODE	UNIT PRICE	PRODUCT CODE
55.8mm (2.2 in.)	Variable	Film Positive	\$ 8.00	11	\$10.00	51
55.8mm (2.2 in.)	Variable	Film Negative	10.00	01		
72.6cm (28.6 in.)	Variable	Paper	8.00	23	12.00	63
45.5cm (17.9 in.)	Variable	Paper	12.00	24	25.00	64

AIRCHART DATA

AERIAL MAPPING

IMAGE SIZE	PRODUCT FORMAT
27.9cm (9.0 in.)	Paper
27.9cm (9.0 in.)	Film Positive
27.9cm (9.0 in.)	Film Negative
45.7cm (18.0 in.)	Paper
68.6cm (27.0 in.)	Paper
91.4cm (36.0 in.)	Paper

BLACK and WHITE

UNIT PRICE	PRODUCT CODE
\$ 3.00	23
5.00	13
6.00	03
10.00	24
15.00	25
20.00	26

COLOR

UNIT PRICE	PRODUCT CODE
\$ 7.00	63
15.00	53
25.00	64
30.00	65
50.00	66

PHOTO INDEXES

IMAGE SIZE	PRODUCT FORMAT
25.4x30.5cm (10x12 in.)	Paper
OTHER	Paper

BLACK and WHITE

UNIT PRICE	PRODUCT CODE
\$5.00	36
5.00	37

FILM SOURCE

B & W - Size A
B & W - Size B

NASA RESEARCH

IMAGE SIZE	PRODUCT FORMAT
55.8mm (2.2 in.)	Film Positive
55.8mm (2.2 in.)	Film Negative
11.4cm (4.5 in.)	Paper
11.4cm (4.5 in.)	Film Positive
11.4cm (4.5 in.)	Film Negative
22.9cm (9.0 in.)	Paper
22.9cm (9.0 in.)	Film Positive
22.9cm (9.0 in.)	Film Negative
22.9x45.7cm (9x18 in.)	Paper
22.9x45.7cm (9x18 in.)	Film Positive
22.9x45.7cm (9x18 in.)	Film Negative
45.7cm (18.0 in.)	Paper
68.6cm (27.0 in.)	Paper
91.4cm (36.0 in.)	Paper

BLACK and WHITE

UNIT PRICE	PRODUCT CODE
\$ 3.00	11
4.00	01
3.00	22
4.00	12
5.00	02
3.00	23
6.00	13
6.00	03
6.00	31
10.00	14
12.00	04
10.00	24
15.00	25
20.00	26

COLOR

UNIT PRICE	PRODUCT CODE
\$10.00	51
7.00	62
12.00	52
7.00	63
15.00	53
20.00	69
30.00	56
25.00	64
30.00	65
50.00	66

MISCELLANEOUS

MICROFILM

FORMAT
16mm (30.5m/100 ft.)
35mm (30.5m/100 ft.)

BLACK and WHITE

ROLL PRICE	PRODUCT CODE
\$15.00	72
20.00	72

COLOR

ROLL PRICE	PRODUCT CODE
\$40.00	73
45.00	73

KELSH PLATES

FORMAT
Contact Prints on Glass Specify thickness (0.25 or 0.06 inch) and method of printing (emulsion to emulsion or through film base).

BLACK and WHITE

UNIT PRICE	PRODUCT CODE
\$12.00	70

TRANSFORMED PRINTS

FORMAT
From convergent or transverse low oblique photographs

BLACK and WHITE

UNIT PRICE	PRODUCT CODE
\$ 8.00	71

VIEWING SLIDES

FORMAT
35mm mounted duplicate of available printing master

COLOR

UNIT PRICE	PRODUCT CODE
\$ 1.00	50

NOTE 35mm original will require additional \$5.00, not to include cost of mounted duplicate

Complete roll reproduction delivered in roll format carries a 50% reduction in frame pricing. Custom processing of non standard products is available at three times the standard product price. If a non-standard size is desired, the cost is three times the next larger standard product price. Priority service with guaranteed five working days shipment is offered for standard products only, at three times the standard product price. Extra care should be taken to insure that monies and related order forms are forwarded to the same facility.

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APPENDIX IV

COST ANALYSES AND ACCURACY ASSESSMENT

It is very difficult to make realistic cost and accuracy comparisons between computer implemented land use mapping and visual interpretation methods. Because of the highly experimental nature of the work done thus far with LANDSAT data, cost and accuracy statistics vary greatly between these two basic approaches and within each approach. Both approaches seem to be cheaper than conventional methods emphasizing medium to low altitude aircraft photography or ground survey work. This is especially true as the size of the study area increases. Computer processed LANDSAT data is faster and is generally more accurate than visual interpretation but considerably more expensive at the present time.

Table IV - 1 shows the cost differences between different computer implemented techniques for mapping Level I land cover from LANDSAT satellite data. The table also compares these costs to those one might expect from a comparable study carried out with conventional aerial photography.

Table IV - 1 Cost comparison of conventional photo interpretation of aerial photography and computer aided analysis of LANDSAT images

	Project (Cost/sq. mile) ^{1/}				
	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>
Aerial Photography- Interpretation	\$3.59	\$.48	\$4.94	NA	\$4.88-5.11
Computer Analysis- Landsat Data	\$1.52	\$.13	\$.25-.79	\$.91	\$.35- .42

^{1/} References for projects:

- A) (Includes some Level II categories) Paul W. Mausel, et. al. "Regional Land Use Classification Derived from Computer-Processed Satellite Data", AIP Journal, April, 1976, p. 160.
- B) Katherine A. Fitzpatrick, "Final Report - Volume 6, "Central Atlantic Regional Ecological Test Site (CARETS) Project, USGS, Reston, Va., 1975.
- C) (Range based on 1974 US project costs) Earth Satellite Corporation and Booz-Allen Applied Research Cooperation for USGS, "Earth Resources Survey Benefit-Cost Study," Appendix 5, November, 1974.
- D) Estimate from Bendix Aerospace System Division, June, 1976.
- E) Edwin L. Thomas, Director of Comprehensive State Planning, in a presentation of the Maryland Department of State Planning LANDSAT Findings, NCSL Task Force Hearings, Annapolis, Maryland, June 30, 1976.

Table IV - 2 gives a breakdown on the costs involved in implementing the visual interpretation approach outlined in the preceding pages. It is important to recognize that costs can be quite variable. In the case of Boone County, the cost of the entire image was charged to one county. Usually 15 to 20 counties are found on one LANDSAT image. The costs do not include any expenses involved in ground truthing the final product obtained for Boone County. The hours involved in the other activities will be variable depending on the skill of the interpreter.

Table IV - 2 Cost of the direct tracing visual interpretation approach for developing Level I land use map for Boone County, Missouri (Area = 685 sq. miles)

<u>Activity</u>	<u>Hours</u>	<u>Cost/Mi²</u>
Premapping Preparation		
A) Gathering support data	4	.03
B) Image familiarization	5	.04
Overlay Preparation	2	.01
Generalized Map	4	.03
Detailed Map	10	.07
Materials ^{1/}	--	<u>.07</u>
		\$.25

^{1/} Materials include the cost of the image plus other mapping materials including acetates, pencils, etc.

Accuracy estimates are more consistent from one technique to another than one costs. Generally, most computer implemented studies attain accuracy rates of 90 to 95 percent for a Level I classification. Accuracy rates of 80 to 90 percent are obtainable using a visual interpretation approach. Hudson and Elifrits (1976) reported an accuracy rate of 90 percent utilizing a direct tracing method with 1:250,000 scale color composites. Table IV - 3 lists some accuracy rates reported by Vegas (1974). Vegas employed a visual interpretation approach using Band 5 LANDSAT images enlarged to a scale of 1:250,000.

Table IV - 3 Accuracy of LANDSAT Level I interpretation over select townships in Harrison County, Mississippi

A. Evaluation by Total Area

<u>Township</u>	<u>Total Area (Acres²)</u>	<u>Area Correct</u>	<u>% Correct</u>
Urbanized	20,829	13,280	63.8
Intermediate	22,005	16,390	74.5
Rural	23,495	19,550	83.2

B. Evaluation by Selected Sample Points

<u>Township</u>	<u>Number of Points</u>	<u>Number Correct</u>	<u>% Correct</u>
Urbanized	520	248	47.7
Intermediate	310	231	74.5
Rural	252	222	88.1

C. Evaluation of Center Points of 40 Acre Plots

<u>Township</u>	<u>Number of Points</u>	<u>Number Correct</u>	<u>% Correct</u>
Urbanized	575	416	72
Intermediate	576	461	80
Rural	575	560	97

Overall accuracy rates for the nine counties mapped during the pilot study were qualitatively estimated by the students as ranging from 70 to 90 percent.

Table IV - 4 lists the accuracy rates for Boone County as determined by the checking of 437 randomly selected points. Although no minimum mapping unit size was established for the mapping task the smallest units mapped average close to 40 acres in size. The sample points checked were roughly the same size. The sample points were checked for accuracy against NASA high altitude aircraft color infrared photography flown six months after the LANDSAT image interpreted was acquired, ASCS black and white photography flown in 1968 and some medium scaled black and white photography flown by Abrahms Aerial Survey in 1971. Additionally, road traverses were made of selected areas to verify the interpretation of both the satellite imagery and NASA aircraft photography.

The accuracy percentages are biased for a number of reasons. First, only approximately 3/4 of the county was sampled thus introducing an area bias. Second, some of the photography used as ground truth was outdated. Inaccurate interpretation of ground truth photography introduces further bias. Finally the sampling procedure itself was not without bias. The selection procedure was random but not stratified and this added to the statistical inaccuracy of the final figures.

Table IV - 4 Accuracy check by sample points for Level I land use categories in Boone County, Missouri.

<u>Category</u>	<u>Total No. of Points</u>	<u>Total No. Correct</u>	<u>% Correct</u>
Urban/built-up	22	18	81
Cropland & Pasture	282	187	66
Cropland (Row crops & small grains)	156	95	61
Pasture	126	92	73
Forest	100	85	85
Water	20	20	100
Disturbed	15	13	86
Overall Total	439	323	74

The cropland category had the lowest accuracy level of all categories. There are some definite reasons for the misinterpretation. There were 18 points classified as forest which were areas appearing identical to wet plowed soil. Positions on the landscape and field patterns would assist in reducing these errors. There were 43 areas classified as cropland that were pasture. The lush growth of well managed pastures made these areas look like winter wheat.

Area misclassified as pasture were generally forest or cropland. Wheat was sometimes confused as pasture. An image taken in the fall could help to separate wheat from pasture.